FY1999 NASA Performance Report

Aero-Space Technology ■ HEDS ■ Earth Science ■ Space Science ■ Crosscutting Processes

MESSAGE FROM THE ADMINISTRATOR

NASA had a momentous year in Fiscal Year (FY) 1999. We met 81 percent of our performance targets and our successes far outweighed our failures. The context of our FY 1999 performance must be evaluated against the challenges that we undertook to answer fundamental questions, develop and apply new technologies, and focus on scientific research.

As a Research and Development Agency, we have struggled with the challenge of establishing annual goals which are both realistic and still accurately represent both the longer time horizons required for our efforts to come to fruition and the difficult tasks that we have set for ourselves. If we were able to accomplish all of our annual goals, we would have set the bar too low. I believe that we set the bar at an appropriate place for FY 1999.

Predicting the output or outcome of a research and development activity in any given fiscal year is a challenge. We will contiue to work on those tasks that were not accomplished by the end of the reporting period. In fact, a number of them have already been completed as we go to press with this report. We will provide an update of our progress towards that end with our next report.

I thank both the NASA Advisory Council (NAC) and the Inspector General for their independent evaluations. The NAC played an invaluable role in providing qualitative evaluation of our performance, going beyond the question of whether we met specific targets to help put our progress into a broader perspective. The results of both of these independent evaluations have been incorporated into this report.

We have learned a number of lessons during the first full year of implementing the Government Performance and Results Act. Many of these lessons have been incorporated in our planning for FY 2001, and I believe that our approach to measuring and reporting progress will continue to evolve as we gain more experience in implementing this mandate.

Daniel S. Goldin
NASA Administrator

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Introduction

The mission of the National Aeronautics and Space Administration (NASA) is to focus on scientific research and the development and application of new cutting-edge technologies. We seek to answer fundamental questions that have challenged humanity for centuries.

Recent years have seen NASA carry out its mission while downsizing and reducing its budget. NASA has successfully reduced its workforce from a high of nearly 25,000 in fiscal year (FY) 1991 to approximately 18,500 at the end of FY 1999. In constant FY 1999 dollars, NASA's budget has decreased 22 percent within the same period. Even with these resource limitations, NASA still managed to meet 81 percent of its performance targets for FY 1999. The figure is even more remarkable given that NASA is a research and development agency, with a mission of regularly doing things that have never been done before.

Although we have not met every performance target, our successes far outweigh the failures. For the past 7 years, we have cut the cost of missions by two-thirds, have cut the time it takes to develop spacecraft by 40 percent, and are launching—on average—four times as many science missions per year.

The following are highlights of a handful of successes that met NASA's FY 1999 performance targets:

- **Hubble Illuminates Universe's Rate of Expansion**—After 3 years of painstaking measurement, Hubble Space Telescope scientists have revised the value for how fast the universe is expanding, increasing the accuracy of the measurement. The rate of expansion, called the Hubble constant, is essential to determining the age and size of the universe. Measuring the Hubble constant was one of the three major goals for the telescope when it was launched in 1990. *Performance target achieved: "Measure the Hubble Constant within an accuracy of 10 percent," page 8.*

- **The International Space Station Era Begins**—The construction of the International Space Station (ISS), one of the largest engineering project humans have ever undertaken, began in December 1998 when the Space Shuttle *Endeavour* and its crew of six joined the U.S. Unity node to the Russian-built Zarya module. Six months later, the Space Shuttle *Discovery* crew traveled 4 million miles in orbit and performed spacewalks during its mission to the ISS. Shuttle Commander Kent Rominger performed the first Shuttle docking with the ISS, and the crew transferred more than 3,600 pounds of supplies-ranging from food and clothes to laptop computers-readying the orbiting outpost for its first crew of inhabitants later this year. *Performance targets achieved: "Deploy and activate the Russian-built FGB (Functional Cargo Block) as the early propulsion and control module" and "Deploy and activate the first U.S.-built element, Unity (Node 1) to provide docking locations and attach ports," page 38.*

- **Landsat 7 Earth Mapping Spacecraft**—In April, NASA's Earth Science Enterprise successfully launched Landsat 7, a follow-on mapping spacecraft that will provide the Government and industry with the latest space views of our Earth. This information can be used in agricultural planning, urban planning, disaster relief, and a plethora of other commercial applications. *Performance target achieved: "Begin to refresh the global archive of 30-meter resolution data," page 16.*

- **Synthetic Vision**—Limited visibility is the greatest factor in most fatal aircraft accidents. NASA's Langley Research Center entered into agreements with eight industry teams to work toward the creation of Synthetic Vision, a virtual-reality display system for cockpits, offering pilots an electronic picture of what is outside their windows, no matter the weather or time of day. *Performance target achieved: "Identify the contributing causes to be addressed . . . for the aviation safety areas of controlled flight into terrain, runway incursion and loss of control," page 48.*

Background

NASA is a Federal research and engineering agency that accomplishes most of its space, aeronautics, science, and technology programs through nine Field Centers and the Jet Propulsion Laboratory, which is a Federally Funded Research and Development Center (Figure 1). In FY 1999, NASA received budget authority (New Obligations Authority, or NOA) of approximately $13.65 million (Figure 2) and maintained a civil service workforce (Full-Time Equivalent, or FTE) of approximately 18,500 (Figure 3).

NASA's program and support activities are guided by a strategic planning process and strategic management systems that are documented in the NASA Strategic Management Handbook, dated October 1996 and the 1998 NASA Strategic Plan With 1999 Interim Adjustments (NASA Policy Directive 1000.1a). Note that an updated version of the NASA Strategic Management Handbook will be available in March 2000. NASA's vision and mission statements have been extracted from our Strategic Plan and are displayed below.

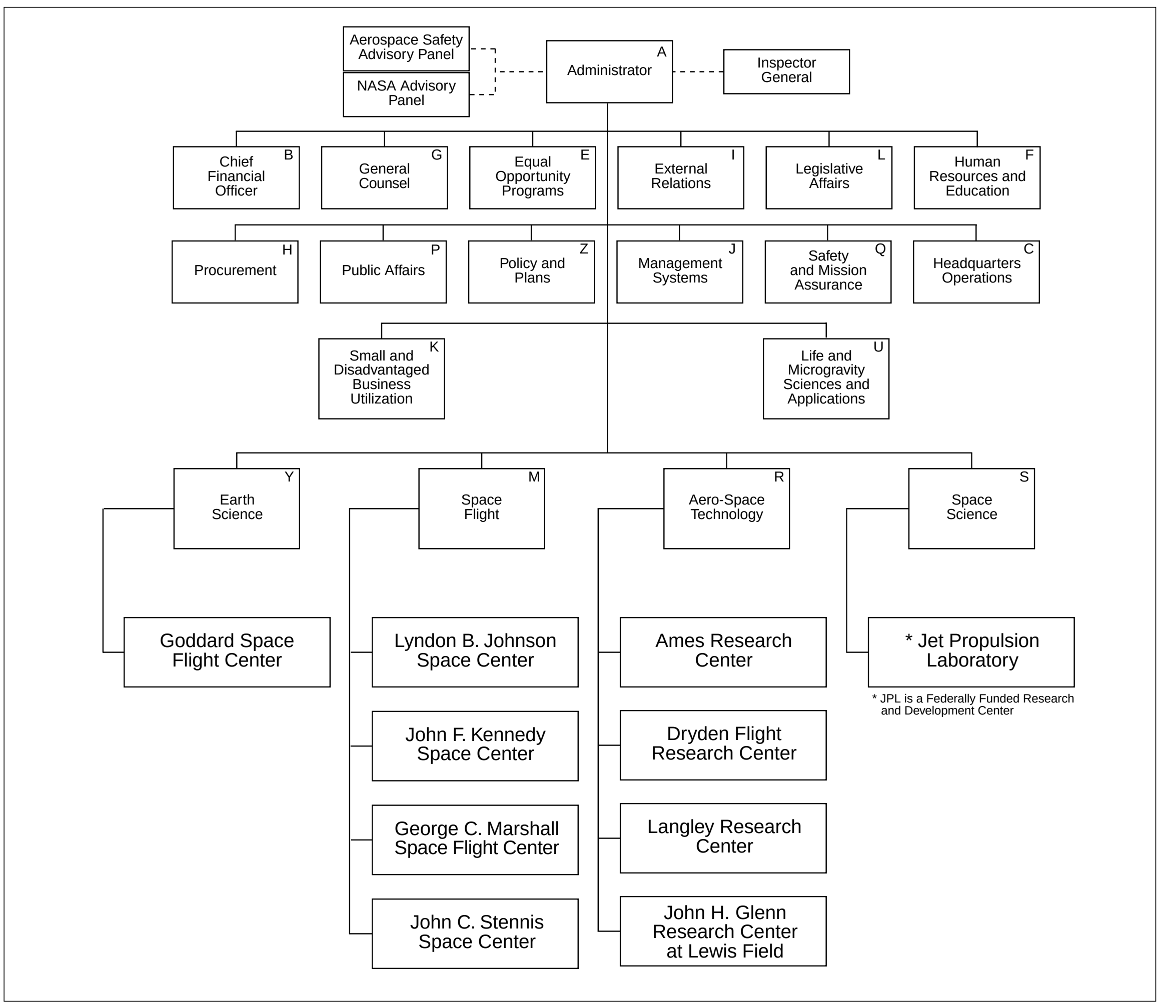


Figure 1. Organization Chart

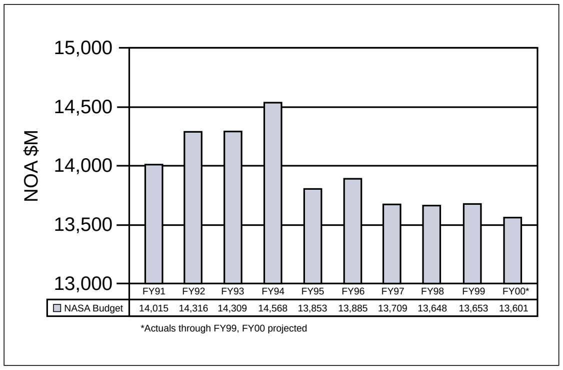


Figure 2. NASA Budget

NASA Vision Statement

NASA is an investment in America's future. As explorers, pioneers, and innovators, we boldly expand frontiers in air and space to inspire and serve America and to benefit the quality of life on Earth.

NASA Mission Statement

- *To advance and communicate scientific knowledge and understanding of Earth, the solar system, and the universe and use the environment of space for research*
- *To advance human exploration, use, and development of space*
- *To research, develop, verify, and transfer advanced aeronautics, space, and related technologies*

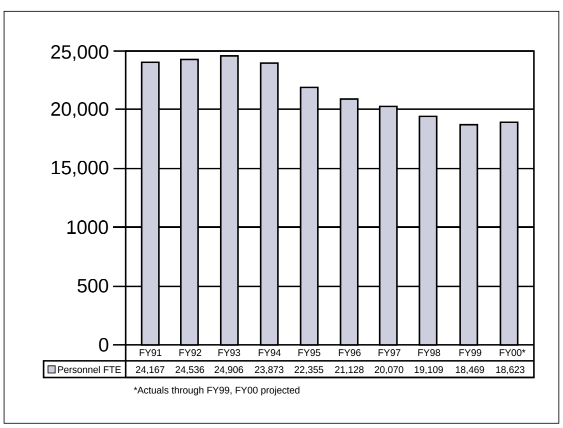


Figure 3. Personnel FTE

NASA's Strategic Management Structure

NASA manages its program activities through four primary Strategic Enterprises:

- Space Science
- Earth Science
- Human Exploration and Development of Space (HEDS)
- Aero-Space Technology

In addition to these Strategic Enterprises, NASA delivers its products and services to customers through four processes that cut across all NASA organizations. These Crosscutting Processes are:

- Mange Strategically
- Provide Aerospace Products and Capabilities
- Generate Knowledge
- Communicate Knowledge

NASA's Approach to Performance Plan Implementation

As an organization with broad objectives and a project orientation, NASA has historically found it necessary to measure its performance against short- and long-term goals. NASA's progress on flight projects is both easy to measure and highly visible. Public attention is drawn quickly to program successes and program failures. Press conferences on the scientific results and program technical status are commonplace. The technical measurement of progress is a management imperative because of the heavy emphasis on development programs and, within the programs, specific projects. Flight programs such as the ISS compile thousands upon thousands of performance metrics on development and fabrication milestones and cost performance. The process of identifying, monitoring, and validating performance on these output measures is essentially "business as usual."

NASA's standard management review processes provide regular and appropriate forums for internal reporting on and the review of project and program

performance data. The recent streamlining of Agency processes provide confidence that new data collection and oversight processes need not be created for compliance with the Government Performance and Results Act (GPRA). Our mission-oriented organizational structure and established management processes are well suited to the assessment of this type of performance evaluation.

However, GPRA requires a heavier focus on *outcome* metrics rather than NASA's typical input and output metrics. As with other Federal agencies engaged in science and technology, NASA has difficulty in quantifying *outcomes* and, especially, relating current outcomes to current fiscal expenditures. This is particularly the case because NASA development programs are multiyear in character. In some cases, the past expenditures began more than a decade ago, such as the Hubble Space Telescope, that entered into development in the mid-1970's. More recently, NASA has focused on programs and projects with much shorter development periods, on the order of 3 to 5 years. Yet, the science outcomes depend on scientists analyzing the information gathered in the years after launch.

The stated objectives of NASA's programs are long term in character. This is exemplified by considering a Space Science Enterprise performance objective: to "solve the mysteries of the universe." Annual performance evaluations assess whether appropriate progress is being made, perhaps actually solving individual "mysteries" to the satisfaction of the scientific community or providing additional insights to the eventual solution of other mysteries. The assessment process requires a multifaceted judgment that takes into account the nature of the challenge of solving the mystery, the level of resources available to be applied, and the actual scientific achievements of the past year.

To assist us in making a connection between our specific annual performance measures and a set of longer range goals and desired outcomes, we are also making use of external reviews with our customers, stakeholders, other agencies, and, specifically, the NASA Advisory Council (NAC). The NAC's independent assessment provides expert opinion that evaluates the progress reported against the quantitative output measures in the context of safety, quality, high performance, and appropriate risk. The NAC's assessment of our overall progress in meeting the objectives documented in both our Strategic Plan and our Performance Plan is provided as one of the sections in this report.

Summary of Performance in Fiscal Year 1999

NASA had a momentous year in 1999. The scope of our achievements extended from new safety technologies for terrestrial airport runways to an independent confirmation of the existence of extrasolar planets. Our activities addressed concerns ranging from the environmental to the cosmological. A number of these events were planned and identified as performance measures in NASA's FY 1999 Performance Plan, such as the refinement of the estimate for the expansion rate of the universe, the stunning images recorded by the Chandra X-ray Observatory, and the provision of a global map of Mars.

Other events were as unanticipated as they were welcome, such as capturing the first optical images of one of the most powerful explosions in the universe—a gamma-ray burst—just as it was occurring. These exciting events and the scientific outcomes that will result from them truly do justify America's investment in NASA and the future.

Other unanticipated events were not so welcome. NASA did not anticipate the delays in initiating the flight testing of the X-34, the extended examination of the wiring in the Space Shuttle fleet, or delays in the launch of Terra, the flagship of the Earth Observing System. These events precluded our ability to deliver all of the performance targets planned for the fiscal year. These unexpected occurrences also illustrate the importance of balancing the imperative to establish and deliver technically difficult challenges with the imperative to assure safety and quality.

Although there were some disappointments, 81 percent, or 117 of the 145, performance targets were fully achieved by September 1999. NASA plans to

continue working toward the completion of 20 of the 28 targets that were not achieved. While it is possible that NASA may fully achieve all 20 targets by the end of FY 2000, there are no guarantees that all technical challenges contributing to the original "underperformance" will be fully resolved by that time. NASA is, nonetheless, enthusiastic about the potential to achieve 95 percent of the planned activities by the end of the next fiscal year.

The evaluation of our unachieved performance targets has enabled us to characterize them in the following manner and to put them into the context of what was achieved in these broad categories (Figure 4).

	Planned Targets	Unachieved Targets	Achieved Targets	FY 2000 Potential
Development Activities	10	2	8	1
Launch Dependency	13	8	5	6
Technology Development	21	4	17	3
Operations/Data Capture	20	2	18	2
Analysis/Publication	35	3	32	4
Education/Outreach	17	3	14	2
Commercialization	6	2	4	2
Other	23	4	19	0
Total	145	28	117	20

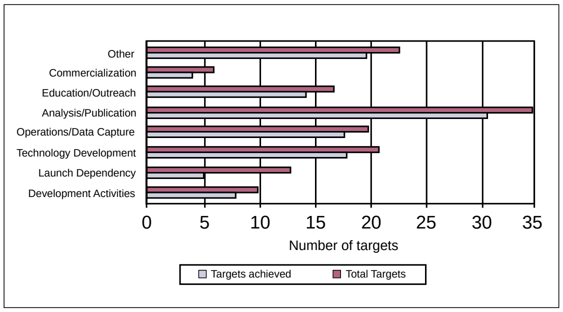


Figure 4. FY 1999 Performance Targets

The largest number of unachieved targets was the result of launch delays. Of the eight launch-dependent targets that were not achieved, six were tied to the delay associated with the launch of Terra. Terra was launched December 18, 1999, and it is anticipated that the data collections planned for FY 1999 will be accomplished in FY 2000.

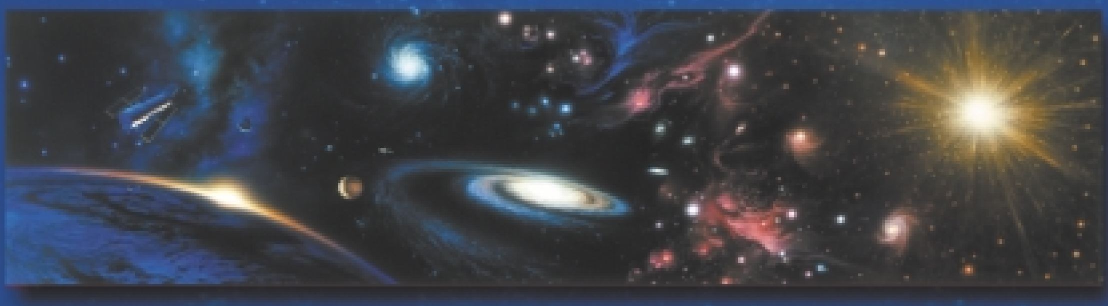
Other targets were written to deliver specific performance levels for FY 1999. Having not realized those levels within the fiscal year, no recovery is possible. Realizing on-time launches for 85 percent of the Space Shuttle missions is one example of this type of binary target wherein NASA either did or did not perform to those levels. In this example, NASA feels strongly that its "Safety First" philosophy is the right approach to the successful operation of the Shuttle orbiter fleet. In several other instances, our performance levels were "close" but not exactly the stated performance level, such as realizing a 97-percent yield on the target of providing monthly mission status updates of a specific set of missions.

The performance on the remainder of the unachieved targets is discussed in the following sections of this report.

Survey of Required Elements for the Performance Report

The balance of this report is organized by Strategic Enterprise or Crosscutting Process and addresses the strategic goals and objectives that were supported by FY 1999 performance measures. Each section:

1. Compares actual performance against the projected performance
2. Explains the reason for not meeting targets that are missed
3. Provides plans for meeting the targets in the future
4. Assesses the impact of FY 1999 performance on future targets, where appropriate
5. Provides supporting information on any program evaluations conducted during the year



"In the Beginning Nothing Became Everything," acrylic by Paul Hudson. In his painting, the artist depicts the birth of the universe, the Big Bang.

Space Science Enterprise

Strategic Goals and Objectives

The goals of the Space Science Enterprise goals are:

- To advance and share fundamental scientific understanding of the cosmos, including charting the evolution of the universe, from origins to destiny, and understanding its galaxies, stars, planets, and life
- To support the exploration and use of space for human enterprise
- To advance the state of allied technologies

The fundamental science goal of the Space Science Enterprise is addressed through several component objectives: to solve mysteries of the universe, to explore the solar system, to discover planets around other stars, and to search for life beyond Earth. To support the human exploration program, the Enterprise uses robotic spacecraft to return reconnaissance information both about characteristics of the planets and other possible human destinations and about space radiation hazards to astronauts. Thus, there are a total of eight Enterprise objectives: four in scientific research, one in education and public outreach, two in support of human exploration, and an overarching one for technology development.

To gauge progress across this spectrum of activities, the Enterprise has established 27 specific project and program performance targets. In addition, broad scientific progress has been assessed against 19 science objectives detailed in the Space Science Enterprise Strategic Plan.

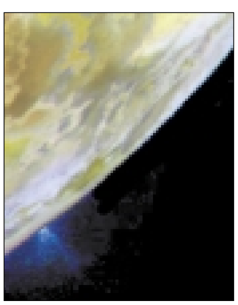


Figure 5. Masubi-Plume on Io

In FY 1999, the Enterprise obtained significant results in many areas. For example, the Origins program completed a major milestone by using the Hubble Space Telescope to derive a greatly improved value for the Hubble constant, H_0 (the rate at which the universe is expanding). The extension of the flagship Galileo mission to the Galileo Europa mission resulted in the capture of fascinating images of the surface of Europa, a moon of Jupiter. When these images are combined with earlier images of Europa, a strong circumstantial case is evolving for an ocean of liquid water below the surface ice crust on Europa. After the Europa series, the spacecraft continued for additional closeups of Io, Jupiter's volcanic innermost moon (Figure 5).

In the technology area, the Deep Space 1 mission successfully demonstrated all 12 of its advanced technology systems, including the first demonstration of an ion drive for primary propulsion. The successful demonstration in space opens the door for each of the validated components to be incorporated into future science missions, resulting in lower cost, better performance, or both.

The Enterprise made significant progress in the education and public outreach area as its wide-ranging and systematic approach to sharing mission and research results began to reach maturity. All new flight programs now have funded components for outreach, and the national space science network for collecting and disseminating educational materials is now in place. These steps lay the groundwork for an expanded realization of the benefits of space science expenditures in American society.

Performance Measures

The Space Science Enterprise successfully completed 24 of the 27 performance targets that were planned for FY 1999. With respect to the three remaining targets, the testing of the metrology components in the Micro-Arcsecond Metrology Testbed should be completed in FY 2000, and an additional rendezvous opportunity for the Near Earth Asteroid Rendezvous (NEAR) spacecraft in February 2000 may enable the Enterprise to successfully complete the two unachieved NEAR targets as well. The annual performance against each of the 27 targets is discussed below.

Goal: Chart the evolution of the universe, from origins to destiny, and understand its galaxies, stars, planets, and life

Objective: Solve mysteries of the universe

Space Science Enterprise spacecraft will chart the evolution of the universe and enhance our understanding of galaxies, stars, and planets. The performance target was to:

- **Successfully launch seven spacecraft, within 10 percent of budget, on average.**

Target achieved: Including the Chandra X-ray Observatory, seven spacecraft have been successfully developed and launched with a 3.8-percent average overrun.

The Hubble Space Telescope continued its observations of the universe. Hubble completed a 3-year research project to determine the expansion rate of the universe (the Hubble constant), which determines the age of the universe. The performance target was to:

- **Measure the Hubble constant within an accuracy of about 10 percent, as compared to previous measurements that differ among themselves by a factor of two.**

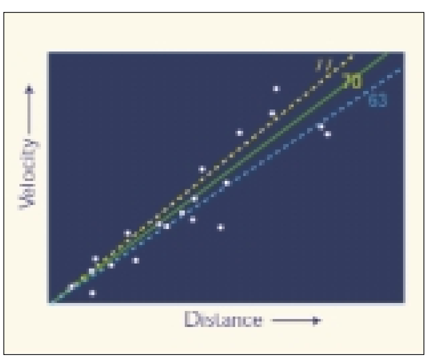


Figure 6. Hubble Diagram for Cepheids

Target achieved: The key project to measure the Hubble constant by observing bright variable stars (Cepheids) in other galaxies was successfully completed (Figure 6). The result, an expansion rate of 70 kilometers per second per megaparsec with accuracy of 10 percent, was publicly announced in late May 1999 and will appear in the refereed professional literature.

The Chandra X-ray Observatory (formerly called the Advanced X-ray Astrophysics Facility) recorded images and spectra of the Milky Way and other galaxies. The performance targets were to:

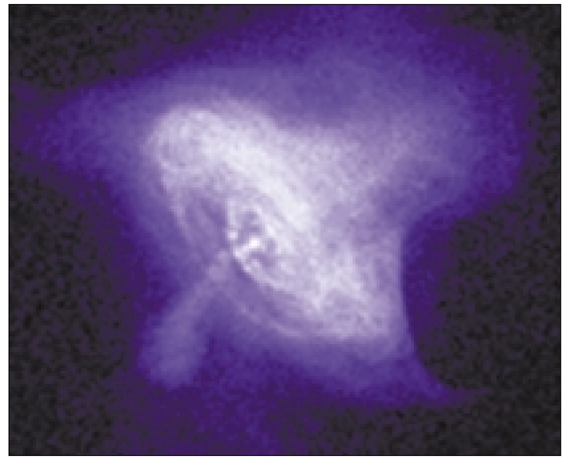


Figure 7. Chandra Supernova Remnant

- **Record 25 images and spectra at a resolution of better than an arcsecond, five to ten times sharper than images gathered earlier by the Einstein Observatory.**
- **Record data on approximately 12 compact stellar objects with a sensitivity 50 times greater than the Einstein Observatory.**

Targets achieved: Chandra was successfully launched on July 23, 1999, and science operations have begun. Both objectives have been met, with the sensitivity of the observatory exceeding expectations (Figure 7).

The Rossi X-ray Timing Explorer (RXTE) was launched in December 1995. RXTE is measuring rapid fluctuations of x-rays from cosmic sources and conducting experiments to test the General Relativity Theory. The performance target was to:

- **Observe physical phenomena 25,000 times closer to the event horizon of black holes than permitted with optical wavelength measurements.**

Target achieved: In achieving the target, RXTE has observed stellar-mass black hole candidates in the galaxy (for example, Cyg X-1 and XTE J1550-56) on time scales down to a few microseconds, probing the in-fall of matter across the event horizon.

Objective: Explore the solar system

The Near Earth Asteroid Rendezvous (NEAR) mission provides high-precision measurements of the shape and composition of the asteroid Eros, increasing our understanding of the early history of such bodies and the solar system. The performance targets were to:

- **Orbit Eros closer than 50 kilometers, 20–30 times closer than previous asteroid flybys.**
- **Measure the shape of Eros to an accuracy of 1 kilometer or better, about 10 times better than previous measurements, and measure the asteroid's mass to an accuracy of 20 percent.**
- **Complete the first direct compositional measurements of an asteroid.**

Targets partially achieved: One of the three targets was successfully completed. The spacecraft failed to achieve orbit during its first encounter in FY 1999, but is functioning well; orbital mechanics permitted a second attempt for the rendezvous, which was successfully executed on February 14, 2000. The shape of the asteroid was measured during the flyby to an accuracy of 600 meters, better than the previous ground-based shape model (3-kilometer accuracy). Per a recent *Science* article, the mass is now known to an accuracy of 25 percent. Composition mapping and a better mass estimate await further data now that NEAR is in orbit.

The Lunar Prospector, launched in 1998, was designed to provide a complete geochemical map of the lunar surface. Research returns also expand knowledge of the early history of the Moon. The performance targets were to:

- **Map the 75 to 80 percent of the Moon's surface not accessible during the Apollo missions conducted from 1969 to 1972.**
- **Provide definitive measurements of the weak lunar magnetic field.**

Targets achieved: Prospector mapped 100 percent of the Moon from a 100-kilometer orbit and at higher resolution from a 30-kilometer orbit (Figure 8).

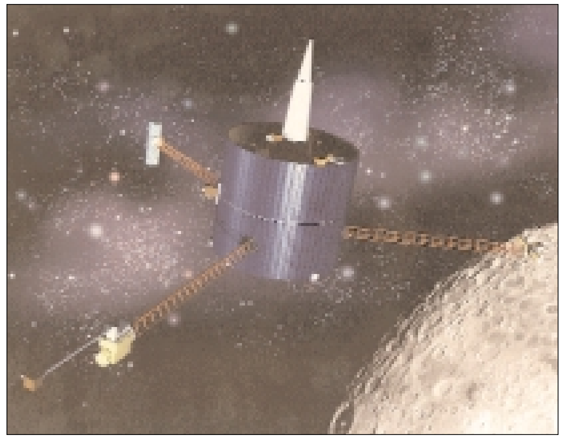


Figure 8. The Lunar Prospector

Definitive measurements of the magnetic field have been completed and published. An add-on experiment featuring a deliberate deorbit of the spacecraft into a polar region to attempt direct detection of possible lunar ice deposits through ground-based observations did not yield positive results.

The Transition Region and Coronal Explorer (TRACE) observed energy propagation from solar disturbances beginning at the bottom of the visible solar atmosphere into the corona high above. The observations were made at both high spatial resolution (a few arcseconds) and high time resolution (a few seconds). The analysis of these data should improve the understanding of solar activity and enhance the ability to predict its occurrence and effects in interplanetary space and on Earth. The performance target was to:

- **Provide these data with spatial resolution five times better than were collected from the Yohkoh Soft X-ray Telescope.**

Target achieved: The target was fully met. The spacecraft is functioning well and continuing to obtain data; TRACE's spatial resolution is 1 square arcsec compared to the Yohkoh Soft X-ray Telescope's 5-square-arcsec pixels (Figure 9). Time resolution is also improved. The results have been published and briefed to various organizations.

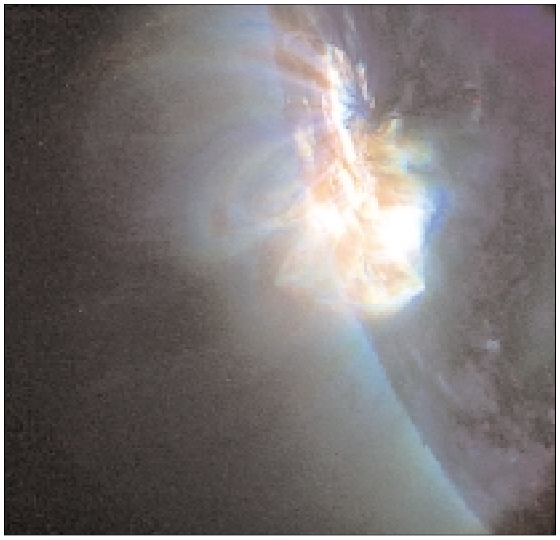


Figure 9. An Example of TRACE's Better Spatial Resolution

Objective: Discover planets around other stars

NASA was to connect the twin 10-meter telescopes at the Keck Observatory in Hawaii into an 85-meter-baseline interferometer. This system should provide a capability to directly detect hot planets with Jupiter-size masses and characterize clouds of dust and gases permeating other planetary systems. The performance target was to:

- **Assemble and lab-test the interferometer beam combiner. This state-of-the-art system will approximately double observational efficiency by using a new approach to fringe detection.**

Target achieved: The combiner system has been assembled, and the approach has been demonstrated in the laboratory.

Objective: Search for life beyond Earth

The Galileo spacecraft will continue to conduct investigations of Jupiter's moon Europa, expanding the understanding of its history. Data collected will help determine the presence and state of water, a central consideration in understanding the possibility of life on the moon. The performance targets were to:

- **Successfully complete and receive scientific data from at least 8 of 10 planned data-taking encounters with Europa.**
- **Bring the total mapping coverage to about 1 percent of the surface at about 30-meter resolution, and multispectral coverage distributed over 50 percent of the surface at lower resolution.**

Targets achieved: The eight required Europa data-taking flybys were successfully completed. Approximately 0.7 percent of the surface of Europa has been covered at 30-meter resolution, but over 90 percent has been covered at lower resolution (Figure 10). The spacecraft is still in operation, and the findings from an additional encounter were released in January 2000.

Figure 10. Europa—Ancient Impact Basin

NASA has established a new Astrobiology Institute to promote the publication of interdisciplinary research, demonstrate investigator interactions, and foster effective public education and outreach on research on life in the universe. To stimulate and facilitate multidisciplinary research, the institute features an innovative virtual organizational structure. In FY 1999, NASA was to select the participating organizations and the institute's director. The performance target was to:

- **Initiate institute operations by linking up to 8 institutions and engaging approximately 50 investigators.**

Target achieved: Eleven member institutions have established video and whiteboard conferencing capabilities, a director has been named, and more than 70 investigators are engaged in research.

Goal: Obtain scientific information in support of human exploration through robotic missions

Objective: Investigate the composition, evolution, and resources on Mars, the Moon, and small bodies

Results from the Mars Global Surveyor (MGS) will provide a greater understanding of Martian geological processes. The MGS will also provide data to determine whether or not water-related minerals are present on the surface. In addition to their immediate scientific interest, MGS data will provide information on potential landing sites for missions of human exploration at a later time. The performance targets were to:

- **Achieve the final science orbit.**
- **Measure the topography with 10-meter precision, about 100 times more accurate than previous measurements.**
- **Provide high-resolution 1.5-meter imaging data, 10 times more detailed than the best imaging from the 1976 Viking mission.**
- **Provide the first thermal infrared spectrometry of the planet.**

Figure 11. Mars Global Surveyor Image of Nanedi Vallis—Possible Evidence of Sustained Water Flow

Targets achieved: The final science orbit has been achieved. Topographic measurements are being collected with a precision better than 1 meter, superior to the required performance. The global composite view challenges our perspective on the formulation of major features of Mars. Imaging continues at 1.5-meter resolution, including some evidence that liquid water may once have existed on the planet, and large numbers of thermal infrared spectra are being acquired (Figure 11).

Magnetic field data suggest that Mars may once have had a dynamo similar to Earth's. This suggests a more Earth-like early Mars and a possibly significant role for water in the early evolution of Mars (Figure 12).

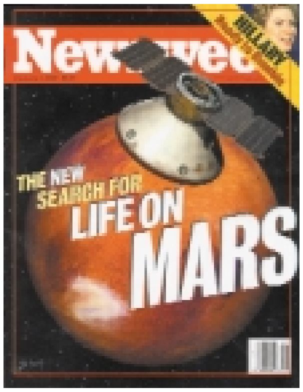


Figure 12. Newsweek Cover of Mars Orbiter Laser Altimeter (MOLA)

Objective: Improve the reliability of space weather forecasting

During FY 1999, the Sun was to approach the most active part of its 11-year cycle. Observations of solar activity were to be conducted with a series of NASA spacecraft, including Polar, Wind, the Interplanetary Monitoring Platform-8 (IMP-8), and the Advanced Composition Explorer (ACE). Data also were to be collected from instruments on two Japanese spacecraft, Geotail and Yohkoh. Information from these missions will help characterize solar emissions and will promote the development of predictive tools to manage the effects of solar activity on Earth. Research on solar activity also contributes to designs for human interplanetary exploration. The performance target was be to:

- **Achieve complete coverage (maximum and minimum) of the solar cycle, an increase from 35 percent.**

Target achieved: The space physics fleet continues to function and collect valuable data as projected. In addition to data obtained from the spacecraft identified above, we are also obtaining valuable data from the Solar and Heliospheric Observatory (SOHO) spacecraft, a joint project of the European Space Agency and NASA, which had been feared lost.

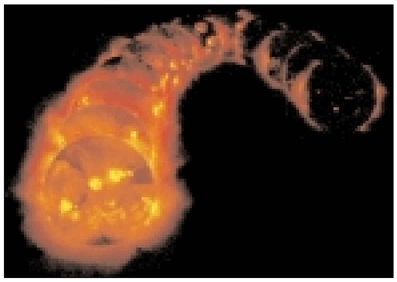


Figure 13. SOHO Images Showing Changes in Solar Activity

Solar maximum occurs over the next 1 to 2 years (Figure 13). A new technique (based on S-shaped markings in the lower solar corona) has been discovered that enables us to make more reliable predictions for coronal mass ejections. SOHO instruments have been used to predict Earth-bound ejections over 80 percent of the solar surface 3 days in advance of their arrival at Earth.

Goal: Develop new critical technologies to enable innovative and less costly mission and research concepts

Objective: Develop innovative technologies for Enterprise missions and external customers

The New Millennium program (NMP) will develop and validate innovative technologies and capabilities that will be required for space science missions planned for the next decade. The performance target was to:

- **Demonstrate an electric ion propulsion system with specific impulse 10 times greater than chemical propulsion systems.**

Target achieved: All 12 candidate technologies on the Deep Space 1 mission were successfully validated in flight. The ion drive demonstration was fully successful. As of September 30, 1999, the engine had operated more than 3,156 hours (the objective was at least 200 hours) and expended only 18 kilograms of xenon propellant to achieve a velocity change of more than 1 kilometer per second, demonstrating a technology that enables missions to shorten both cruise time and propellant weight. Furthermore, the Remote Agent autonomous control software, which won the NASA Software of the Year award, was fully successful. The spacecraft successfully flew by asteroid Braille in July 1999 and is on track to encounter asteroid 1992 KD in July 2000.

The Micro-Arcsecond Metrology Testbed will demonstrate an improvement in positioning accuracy of optical surfaces. This accuracy is important for the development of high-performance interferometers. The performance target was to:

- **Demonstrate an improvement in measurement precision for optical path lengths in laser light to the 100-picometer (million-millionths of a meter) range.**

Target partially achieved: The assembly of the Micro-Arcsecond Metrology Testbed vacuum facility was completed, but the testing of metrology components was not completed by the end of FY 1999. The demonstration will be completed in FY 2000.

The Mars 98 Lander was to demonstrate technologies to reduce mass and power consumption and increase instrument reach and dexterity. The performance target was to:

- **Demonstrate an advanced robotic manipulator with an order of magnitude performance improvement compared to the manipulator used on Viking in 1976.**

Target achieved: Despite the later failure of the Mars Polar Lander to land successfully, the manipulator system passed acceptance tests prior to launch. The demonstration target successfully met was to demonstrate the same reach as the Viking manipulator, but with one-fifth of the mass, one-half of the power, and double the dexterity.

Goal: Contribute measurably to achieving the science, mathematics, and technology education goals of our Nation, and share widely the excitement and inspiration of our missions and discoveries

Objective: Incorporate education and enhanced public understanding of science as integral components of space science missions and research

Space science missions and research programs make a unique contribution to education and the public understanding of science. Providing a steady return of discoveries and new knowledge contributes to the accomplishment of this objective. The performance targets were to:

- **Account for 4 percent of the 150 "most important science stories" in the annual review by *Science News*.**
- **Account for no less than 25 percent of total contributions to the college textbook *Astronomy: From the Earth to the Universe*.**
- **Each new Space Science Enterprise mission initiated in FY 1999 will have a funded education and outreach program.**
- **The Space Science Enterprise will complete an organized network of contacts by the end of FY 1999 to work with educators and space scientists to formulate and implement space science education and outreach programs. This network will be available to every State in the United States.**

Targets achieved: The most recent *Science News* statistics available indicate that 5 percent of the top 150 science stories were based on space science. A 24-page supplement to the college textbook was published in 1999; combining the portion of the new material based on NASA's space science program with the previous analysis of the most recent edition of the textbook, the new total contribution is 31 percent. Each mission initiated in FY 1999 had a funded education and outreach program, and the Enterprise outreach contact network is now in place. A representative activity of the program was the electronic field trip "Live from the Sun," which reached up to 2 million teachers and students

Space Science Advisory Committee Evaluation

The Space Science Advisory Committee (SSAC) was asked to evaluate the Enterprise's advance toward near-term science objectives in the 1997 Space Science Enterprise Strategic Plan, in addition to the evaluation of the FY 1999 performance targets and objectives discussed in the NASA Advisory Council chapter of this report.

The Enterprise conducted a self-assessment that was amended and approved by the SSAC. Progress in 16 of 19 research objective areas was assessed as fully satisfactory ("Green"). In three areas, progress was not fully up to expectations:

- "Test the General Theory of Relativity"—The Gravity Probe B mission is experiencing technical, schedule, and budget problems, which are currently being analyzed for impacts and solutions.
- "Characterize the history, current environment, and resources of Mars, especially the accessibility of water"—The Mars Climate Observer was lost on orbit insertion. A failure review has been conducted with recommendations for improvements to general mission operations. The Mars Polar Lander and Deep Space 2 missions were later lost, and failure reviews have been convened. However, other research continues to utilize data from the Mars Global Surveyor.
- "Observe the evolution of galaxies and the intergalactic medium"—The Wide-field Infrared Explorer (WIRE) mission experienced a catastrophic failure, and the prime science mission was lost. The spacecraft is now being used for engineering testbed experiments and collecting some secondary, but useful, data sets.

Validation and Verification in the Space Science Enterprise

The Space Science Enterprise holds each of the program and project managers fully accountable for the accuracy of the performance information that is duly reported through the normal management and reporting processes. A review of the progress against each of the targets has been incorporated into management reviews at all levels within the Space Science Enterprise organizations.

"Amazon Rivers," batik on silk by Mary Edna Fraser. This painting depicts NASA's efforts to better understand our environment. The work aims to honor Earth's fragility and perhaps conveys a peaceful environmental communication linking humankind.

Earth Science Enterprise

Strategic Goals and Objectives

The Earth Science Enterprise mission is to understand the total Earth system and the effects of natural and human-induced changes on the global environment. The goals and objectives are as follows:

- Expand scientific knowledge of the Earth system using NASA's unique capabilities from the vantage points of space, aircraft, and *in situ* platforms:
  - Understand the causes and consequences of land-cover/land-use change
  - Predict seasonal-to-interannual climate variations
  - Identify natural hazards, processes, and mitigation strategies
  - Detect long-term climate change, causes, and impacts
  - Understand the causes of variation in atmospheric ozone concentration and distribution

- Disseminate information about the Earth system:
  - Implement open, distributed, and responsive data system architectures
  - Increase public understanding of Earth system science through education and outreach

- Enable the productive use of Earth Science Enterprise science and technology in the public and private sectors:
  - Develop and transfer advanced remote-sensing technology
  - Extend the use of Earth Science Enterprise research to national, State, and local applications
  - Support the development of a robust commercial remote-sensing industry
  - Make major scientific contributions to national and international environmental assessments

Programs of the Enterprise advance the new discipline of Earth system science, with a near-term emphasis on global climate change.

Performance Measures

Of 35 targets, 25 were fully achieved. Of the remaining targets, seven were deferred to FY 2000 because of circumstances beyond our control—for example, the recertification of the commercially procured launch vehicle for the Terra spacecraft and issues related to Russian participation with the third Stratospheric Aerosol and Gas Experiment (SAGE III) mission. For six of these deferred targets, other activity is noted that partially recovers the science objectives. Two targets were not fully achieved because data analysis and publications lagged behind schedule. One target was not fully achieved, although progress toward the objective was significant; the Enterprise involved 7,767 Global Learning and Observations to Benefit the Environment (GLOBE) schools while the target had been set at 8,000.

Goal: Expand scientific knowledge by characterizing the Earth system

FY 1999 was a year of substantial scientific accomplishment in our understanding of the major elements that comprise the Earth system.

Over the oceans, the Earth Science Enterprise:

- Reduced the uncertainty in global rainfall over the tropics by one-half helping, improve the prediction of both short-term weather and the global availability of fresh water
- Produced near-daily ocean color maps that help us understand the role of oceans in removing carbon dioxide from the atmosphere
- Documented the waxing and waning of El Niño, enabling seasonal climate prediction (Figure 14)
- Resumed the global measurement of winds at the ocean surface to improve short-term weather prediction and the global tracking of major hurricanes and tropical storms

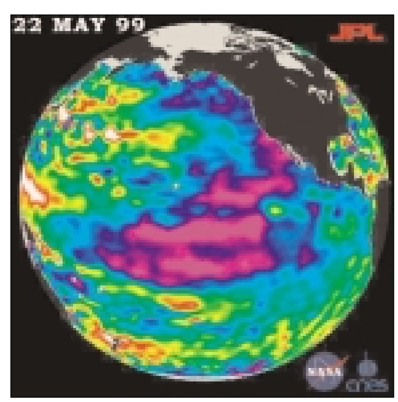


Figure 14. EL Niño Documentation

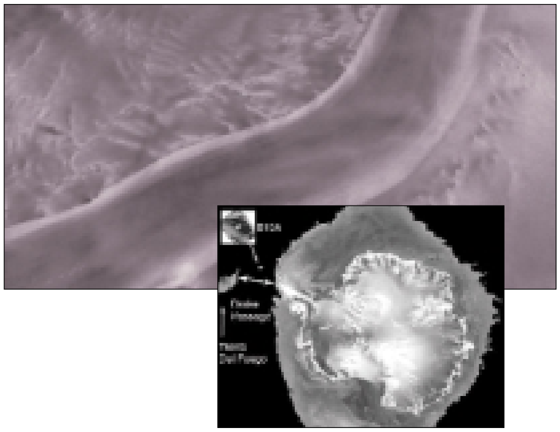


Figure 15. First Detailed Radar Map of Antarctica

Over the ice caps, the Enterprise:

- Determined the thinning and thickening rates for the Greenland ice sheet
- Provided the first detailed radar mosaic of Antarctica (Figure 15)
- Provided daily observations of the polar regions from space

Over the land, the Enterprise:

- Produced the first satellite-derived assessments of global forest cover
- Began refreshing the global archive of 30-meter land-cover data
- Conducted an international field experiment in the Amazon region to help understand the role of vegetation on Earth in removing carbon dioxide from the atmosphere

In solid Earth studies, the Enterprise:

- With the U.S. Geological Survey, measured surface displacement, a precursor to earthquakes, in the Los Angeles basin

In the atmosphere, the Enterprise:

- Continued to measure concentrations of both ozone and ozone-depleting substances and assess the recovery of upper ozone correlation
- Implemented a 17-year data record of aerosols and cloud properties toward predicting annual-to-decadal climate variations

Objective: Understand the causes and consequences of land-cover/land-use change

The carbon cycle is one of the major Earth system processes influencing global climate. In this area, NASA's contributions are monitoring land-cover changes and measuring terrestrial and ocean biological processes to estimate carbon uptake, thereby modeling their role in the global carbon cycle. Important unknowns in the carbon cycle are seasonal rates of carbon storage in the ocean caused by the activity of phytoplankton, which can be monitored from space. The performance targets were to:

- **Begin to refresh the global archive of 30-meter land imagery from Landsat 7, two to three times per year. A single global archive has not been constructed since the late 1970's. Landsat 7 also includes a 15-meter panchromatic band, for the study of ecosystems disturbance.**

Target achieved: Earth science began refreshing the global archive of 30-meter land imagery after the Landsat 7 satellite was launched on April 15, 1999. Mission Operations is acquiring 90,000 scenes per year. High-quality data distribution began on August 23, 1999, and a public announcement was made on August 30, 1999. Seasonal image collection to refresh the global archive began in July 1999, and more than 50,000 acquisitions were archived. There has been one global acquisition and a partial refresh in FY 1999. A rate of two to three global terrestrial acquisitions a year will be achieved after a full year of operation.

- **Begin to collect near-daily global measurements of the terrestrial biosphere (an index of terrestrial photosynthetic processes from which calculations of carbon uptake are made) from instruments on the Earth Observing System (EOS) Terra (AM-1) spacecraft.**

Target not achieved: This was deferred to FY 2000 because of the delay in the Terra launch. Other activity occurred to partially recover science objectives. The Moderate Resolution Imaging Spectrometer (MODIS) instrument was tested and integrated on the spacecraft. The achievement of this target in FY 2000 is anticipated with the successful launch of Terra in December 1999. The continuing availability of the Advanced Very High Resolution Radiometer (AVHRR) terrestrial biosphere data stream has enabled daily global measurements of the terrestrial biosphere. Recent work applying new continuous classifiers to the AVHRR data have produced the first satellite-derived global data products of the percentage of tree cover. These data have already been used to improve estimates of global carbon stocks in forests. However, the AVHRR data are not of the resolution or quality that will be achieved with MODIS.

- **Collect near-daily global measurements of ocean color (an index of ocean productivity from which calculations of ocean update of carbon are made).**

Target not achieved: Data collection was deferred to FY 2000. The achievement of this target in FY 2000 is anticipated with the successful launch of Terra in December 1999. The launch of MODIS on Terra will increase the global coverage of ocean color to every 2 to 3 days, increasing coverage nearly fourfold, adding new information about primary productivity, and improving statistics on variability. The continued purchase of Sea-viewing Wide Field-of-view Sensor (SeaWiFS) data has somewhat mitigated the impact of the Terra delay. ORBIMAGE is distributing SeaWiFS data to the science community through a commercial data buy. The SeaWiFS project has been routinely producing 8-day global maps of ocean color since September 1997 (Figure 16).

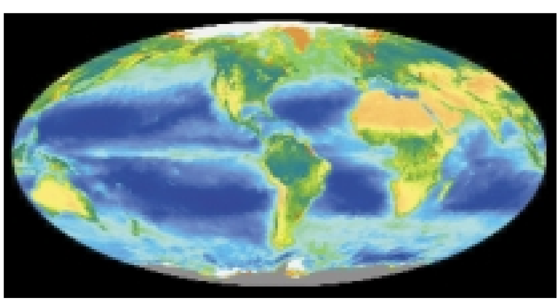


Figure 16. A Global Map of Ocean Color

Objective: Predict seasonal-to-interannual climate variations

In FY 1999, the Earth Science Enterprise continued to invest in observations, research, data analysis, and modeling in this area. The Tropical Rainfall Measuring Mission (TRMM), launched in 1997, continued to gather information on rainfall in the tropics, where two-thirds of global precipitation falls. This is the key to understanding Earth's hydrological cycle, one of the three major processes driving Earth's climate and the global heat balance that drives seasonal change. The performance targets were to:

- **Begin the second of a 3-year sequence of instantaneous measurements of rainfall rates and monthly accumulations in the global tropics. This will be the first-ever measurement of global tropical rainfall. Current uncertainty in global tropical rainfall estimates is 50 percent; TRMM data will reduce this uncertainty to 10 percent, an 80-percent improvement.**

Target achieved: The second year of this 3-year sequence of measurements was accomplished, and the data are available for NASA-selected TRMM and affiliated investigators on the TRMM Data and Information System (TSDIS). TRMM data are available to the general public through the EOS Data and Information System (EOSDIS) at the Goddard Space Flight Center and Langley Research Center Distributed Active Archive Centers (DAAC). Based on these measurements, the uncertainties associated with knowledge of global distribution of tropical rainfall was decreased from 50 percent to 25 percent on the way to 10 percent by FY 2001, the end of nominal mission life.

- **Begin the measurement of sea-surface wind speed and direction at a spatial resolution of 25-kilometer resolution over at least 90 percent of the ice-free global oceans every 2 days. This represents a resolution increase of a factor of two and a 15-percent increase in coverage over previous measurements. Data from this mission will be used to improve the short-term weather forecasts.**

Target achieved: The target was achieved with the launch of the Quick Scatterometer (QuikSCAT) spacecraft, which joins TRMM and the Ocean Topography Experiment/Poseidon (TOPEX/Poseidon) to form a powerful suite of space-based observational assets to track phenomena such as El Niño and La Niña. QuikSCAT data are now available on the World Wide Web from the Physical Oceanography DAAC at the Jet Propulsion Laboratory (JPL). Resolution in the QuikSCAT standard product increased by a factor of two over the NASA Scatterometer (NSCAT)—from 50 to 25 kilometers—and QuikSCAT demonstrated a 15-percent increase in daily coverage of ocean areas (non-ice), from 77 percent for NSCAT to 93 percent for QuikSCAT.

Objective: Identify natural hazards, processes, and mitigation strategies for floods, droughts, and volcanoes

Earthquakes, volcanic eruptions, landslides, wildfires, floods, storms, and other severe events threaten the lives and property of thousands of humans each year. Economic losses from natural disasters are estimated to average approximately $50 billion per year in the United States and approximately $440 billion per year worldwide. Such losses will continue to rise as society continues to move into and build in high-risk areas such as coastlines. Other factors, such as climatic variations causing changes in the magnitude and frequency of some natural events, will affect the magnitude of losses from natural disasters (Figures 17 and 18). Highlights for the year include:

- The Southern California Integrated Global Positioning System Network was expanded to more than 150 of 250 planned continuously operating stations. An analysis of the current stations and interferometric Synthetic Aperture Radar (SAR) data have identified high rates of shortening in northern metropolitan Los Angeles, adding to a higher risk of earthquakes in this particular region.
- Interferometric SAR data have been used to identify and model the emplacement and movement of magma within active volcanoes, including Mt. Etna in Italy and Mammoth Mountain in California. This has provided insights into the internal workings of the volcanoes as well as assessments of their state of activity.
- Data from the ESA Remote Sensing Satellite (ERS), Canada's RADARSAT, the Geostationary Operational Environmental Satellite (GOES), AVHRR, and Landsat have been used to observe, study, and monitor floods worldwide. These data and studies are being used to assess the vulnerability of society and infrastructure as well as the possible environmental impacts of devastating flood events.
- A new understanding of volumetric erosion rates for volcanic islands and topographic changes at ice-capped volcanoes in the Cascade Range in Washington has been gained.

Figure 17. Before Hurricane Floyd in North Carolina

Figure 18. After Hurricane Floyd in North Carolina

The performance targets were to:

- **Provide instruments sufficient to create the first digital topographic map of 80 percent of Earth's land surface between 60°N and 56°S. The Shuttle Radar Topography Mission (SRTM) will be launch-ready by the end of FY 1999.**

Target achieved: The SRTM instrument was developed to create a near-global high-resolution digital elevation topographic map of the world. The SRTM was delivered to Kennedy Space Center, tested, integrated on *Endeavour*, and launched in February 2000. The data set obtained from SRTM will allow scientists in Federal, State, and local agencies and academia to study the terrain for basic research, such as ecology, geology, geodynamics, hydrology, and atmospheric modeling, as well as applications, such as urban and infrastructure planning and disaster management.

- **Use the Global Positioning System (GPS) array in Southern California to monitor crustal deformation on a daily basis with centimeter precision, and initiate the installation of the next 100 stations. The data will be archived at JPL and run in models, with results given to the California Seismic Safety Commission and the Federal Emergency Management Agency to be used for earthquake warning.**

Target achieved: The GPS array in Southern California is recording and transmitting data on a daily basis, and JPL, Scripps, and other universities and public and private institutions are analyzing the data. Data and solutions for site velocities and time series of site positions are available on the Internet. The scientific results have been reported at conferences. A scientific paper on early Southern California Integrated GPS Network (SCIGN) data by Argus, the JPL analysis group, was published in *Geology* and cited in the press and on television. One hundred sites were drilled during FY 1999, and the next 100 sites will begin in early FY 2000. Federal, State, and local agencies and companies will use these data to study ground deformation related to earthquakes and to continually assess the vulnerability and risk of earthquakes to the region.

- **Data received from GPS receivers in low-Earth orbit will also be used to test improved algorithms for measuring atmosphere temperature. The data will serve as the future prototype for improving short-term weather forecasts globally. The data will be archived at JPL, and the results will be published in science literature.**

Target partially achieved: The results have not yet been published; however, the Ørsted spacecraft is providing limited precision GPS data that JPL is analyzing. The first significant data sets arrived at JPL in late September 1999. Power limitations on the two spacecraft currently limit GPS acquisitions to approximately 6 out of every 27 hours on Ørsted and 8 out of every 48 hours on Sunsat. This will improve somewhat as the orbit sun angles improve. Improved algorithms were tested to deal with data for measuring atmospheric temperature, and there were some subtle improvements over the basic retrieval algorithms used in GPS/metrology variables.

Objective: Detect long-term climate change, causes, and impacts

In FY 1999, information on global and regional studies of temperature and precipitation drivers was collected to measure the solar radiation reaching Earth. Clouds and aerosols (suspended particles in the atmosphere, such as dust, sulfate, and smoke) determine the fate of this radiation in the atmosphere and impact Earth's energy balance. The current uncertainty in Earth's radiation balance is about 15 W/m^2 (watts per meter squared) monthly mean over 100- by 100-kilometer areas. Instruments on Terra are designed to substantially reduce this uncertainty. Goddard Institute for Space Studies (GISS) climate model studies have indicated the possible importance of stratospheric ozone processes for surface climate change, and thus the need for including the upper atmosphere in climate models. The performance targets were to:

■ **Begin to conduct daily observations of cloud properties such as extent, height, optical thickness, and particle size.**

Target not achieved: This was deferred to FY 2000 because of the launch vehicle recertification that pushed the Terra launch into FY 2000. Other activities occurred to partially recover science objectives. The Earth Science Enterprise instruments to achieve this target were tested and ready for flight at the end of FY 1999. The instruments will obtain data on "Beta" cloud products and will be released to the DAAC's approximately 3 months after acquisition, and "science quality" cloud products will be available 24 to 30 months after acquisition. However, work has continued to meet this science objective. Under the International Satellite Cloud Climatology Project (ISCCP), a 17-year data set of cloud properties is nearing completion, with initial ISCCP cloud products available and being used through the Langley Research Center DAAC. In addition, cloud data products from the third First ISCCP Regional Experiment (FIRE III) Arctic cloud experiment conducted in 1998 are available through the Langley DAAC.

■ **Map aerosol formation, distribution, and sinks over the land and oceans.**

Target not achieved: Mapping was deferred to FY 2000. Other activities occurred to partially recover science objectives. The Earth Science Enterprise instruments to achieve this target are tested and ready for flight. However, the Terra launch was delayed until FY 2000 because of launch vehicle recertification. The instruments will obtain data on "Beta" release of aerosol products and will provide data to the DAAC's approximately 6 months after acquisition; "science quality" aerosol products available 24 months after acquisition. The Global Aerosol Climatology Project (GACP) is producing initial climatologies of aerosol optical thickness and particle size parameter using satellite measurements and transport model calculations. Analyses of field experiment measurements have been completed, data products are available from the Langley DAAC, and science results are in publication in special issues of the *Journal of Geophysical Research*. The results of AERONET analyses (aerosol optical thickness and size parameter) are available on the World Wide Web for use in scientific research within 24 hours of acquisition.

■ **Achieve significant reduction in the uncertainty in components of Earth's radiation balance (that is, improved angular models leading to an estimated error reduction in regional-scale monthly-average net radiation of about 50 percent).**

Target not achieved: This was deferred to FY 2000 because of the delay in the Terra launch. Other activities occurred to partially recover science objectives. Terra's Clouds and the Earth's Radiant Energy System (CERES) instrument was tested and ready for flight at the end of FY 1999. The instrument will obtain data on the "Beta" release of radiation flux products, which will be released to the Langley DAAC approximately 3 months after acquisition. Angular models based on measured CERES data will be available 24 months after launch. Reprocessed, reduced uncertainty radiation flux data will be available 30 months after launch. The Earth Radiation Budget Experiment (ERBE) processing project is completing a 15-year radiation budget data set using measurements from the wide-field-of-view instrument on the Earth Radiation Budget Satellite (ERBS). Early portions of this data set are available from the Langley DAAC, which has also received the "Beta"-level release of the CERES data from TRMM. The science assessment of these data is in progress.

Objective: Understand the causes of variation in ozone concentrations and distribution in the upper and lower atmosphere

Fulfilling its congressional mandate for upper atmosphere and ozone research, The Earth Science Enterprise has acquired a 20-year data set on ozone concentration and distribution. The Enterprise continues to explore the chemical processes of ozone destruction and replenishment in the stratosphere and is beginning to probe the complex chemistry of

the troposphere, which is the lower portion of the atmosphere in which we live. The Enterprise employs this capability to make essential contributions to international scientific assessments of ozone by the World Meteorological Organization (WMO). NASA's contributions in this area are to develop and operate space-, airborne-, and ground-based instruments that will map the fluctuations in ozone and related constituent gases and trace elements in the atmosphere. In addition, NASA has a focused research and modeling effort in this area. The performance targets were to:

- **Use new retrieval methods to collect and analyze three new data products, including surface ultraviolet radiation, tropospheric aerosols, and, in certain regions, tropospheric columns. Together with Solar Backscatter Ultraviolet (SBUV)/2 data, there will now be a continuous 20-year data set for total ozone that will measure the ultimate effectiveness of the Montreal Protocol on substances that deplete the ozone layer. These data are also useful in routing aircraft around areas of concentrated volcanic dust. These new and extended data products will be made available on the Total Ozone Mapping Spectrometer (TOMS) web site for dissemination and access to a broader community than to just NASA-sponsored scientists.**

Target achieved: (a) New retrieval methods exist and are producing three new data products, including surface ultraviolet, tropospheric ozone column amounts, and ultraviolet-absorbing tropospheric aerosols. These products are now available; however, further refinements are continually made. (b) Progress has been made on understanding SBUV/2 characteristics. Improvements to the calibration correction, the nonlinearity corrections for the Photomultiplier Tube, and understanding the instrument's orbital hysteresis are complete, and reanalysis is taking place. The reanalysis was applied to the intercalibration and gap filling of the TOMS data. This re-analysis has revealed seasonal features that require further investigation prior to the final release of the new 20-year data set. (c) Data products are available on the TOMS web site.

- **Improve the collection and analysis of measurements provided by SAGE II. These improvements include: lunar occultation capability allowing for new nitrogen trioxide (NO_3) and chlorine dioxide (OClO) measurements; additional wavelength sampling, providing direct measurements and the ability to retrieve aerosols throughout the troposphere; and appreciably higher spectral resolution, allowing significantly improved distributions of water vapor and ozone in the upper troposphere and lower stratosphere. This represents approximately a two-thirds reduction in error in near-tropopause water vapor measurements, as well as the extension of ozone measurements into the midtroposphere with 10- to 15-percent errors. Such data were not available before.**

Target not achieved: This was deferred to FY 2000. Completing this target depends on the spacecraft launch, which slipped to FY 2000 because of the delay of Russian implementation. The SAGE III instrument is complete and will be integrated on the Meteor 3M spacecraft in FY 2000. Another activity occurred to partially recover science objectives. The Earth Science Enterprise purchased Polar Ozone and Aerosol Measurement (POAM) data through the data buy program, which helps fill the gap for stratospheric ozone and aerosol profiles caused by the SAGE III launch delay.

- **Initiate the full Southern Hemisphere Additional Ozonesonde network to obtain the first-ever climatology of the upper tropospheric ozone in the tropics.**

Target achieved: The implementation of the network is complete.

- **Continue the detailed multi-aircraft study of troposphere chemistry over the tropical Pacific Ocean, especially the contribution of the long-range transport of air from South America and Africa to otherwise unpolluted areas. Complete the field measurements phase of the Pacific Exploratory Mission**

(PEM)-Tropics B (rainy season) with an improved payload that has resulted from an initiative to develop a smaller, lighter payload with equal or better performance than PEM-Tropics A (dry season). The results will be fully analyzed and published.

Target partially achieved: PEM-Tropics field operations were completed in April 1999. The data were released to public archives in December 1999. Data analysis and publication will be completed in FY 2000.

- **Measure surface levels of chlorine- and bromine-containing chemical compounds addressed under the Montreal Protocol to document the decreasing concentrations of the regulated compounds and the rising concentrations of their replacements to quantify the decrease in total halogen abundance in the lower atmosphere. The data will be provided to researchers supporting the WMO assessment process.**

Target achieved: The analyses were incorporated in the United Nations Environment Programme (UNEP)/WMO "Assessment of Ozone Depletion 1998" Monitoring Project Report #44, which was completed in FY 1999 and has been distributed internationally.

Objective: General Earth Science performance measure—Successfully launch spacecraft

In addition to launching spacecraft, work continued on the development of numerous spacecraft and instruments scheduled for launch in future years. The development of the Vegetation Canopy Lidar (VCL), EOS Aqua (PM), EOS Chemistry, Gravity Recovery and Climate Experiment (GRACE), Jason-1, and ICESat missions continued in FY 1999. Work was initiated on the Solar/Stellar Irradiance Comparison Experiment (SOLSTICE), Pathfinder Instruments for Cloud and Aerosol Spacebourne Observations/ Climatologie Etendue des Nuages et des Aerosols (PICASSO-CENA), CloudSat, Triana, and QuikTOMS.

- **Successfully launch three spacecraft, within 10 percent of budget on average.**

Target not achieved: The Enterprise successfully completed the Landsat 7 and QuikSCAT launches. Landsat 7 will build on the heritage of the Landsat program in building a 3-decade-long record of terrestrial ecosystems and their change. The Terra launch, originally planned for FY 1999, took place on December 18, 1999.

Goal: Disseminate information about the Earth system

The Earth Science Enterprise is fulfilling its commitment to make its Earth observation data widely available for research and education. Almost 1,300,000 distinct users obtained 5.2 million data products during the year. The Enterprise sponsored 350 workshops to train more than 11,000 teachers in the use of Earth science concepts and teaching tools, and it awarded 50 new fellowships to maintain support for 150 graduate students at U.S. universities annually to train the next generation of Earth scientists.

Objective: Improve the dissemination of Earth Science Enterprise research results

The dissemination of information resulting from Earth Science Enterprise research is accomplished through EOSDIS. Distribution systems have been improved and new methods have been developed to place data in the hands of Enterprise customers in a timely manner through open, distributed, and responsive data system architectures. EOSDIS is now poised and ready to support Terra, Aqua, and other Earth science missions. The performance targets were to:

- **Make Earth science data on land-surface characteristics, ocean-surface conditions, and climate available to users within 5 days.**

Target achieved: EOSDIS has been routinely providing Earth science data products to end users within 5 days of receipt or production of the requested data

product. These products consist of data from currently operating space assets, including precipitation measurements and observations of tropical storms from TRMM, ocean productivity measurements from SeaWiFS, the detection of ocean-surface height changes used to predict El Niño occurrence and strength from TOPEX/Poseidon, and sea ice motion and Antarctic mapping from Canada's RADARSAT. The data provided also include measurements of stratospheric trace chemicals from the Upper Atmospheric Research Satellite (UARS), Antarctic ozone hole measurements from TOMS, land-use and land-cover data from the heritage Landsat missions, and measurements of Earth and solar radiation from ERBE.

- **Increase the volume of data archived by 10 percent compared to FY 1997 (126 terabytes).**

Target achieved: As of the end of FY 1999, the EOSDIS archive volume was 284 terabytes. The EOSDIS archive volume for FY 1999 will have increased by at least 125 percent since FY 1997, greatly exceeding our objective of a 10-percent growth in the archive volume (Figure 19). The Landsat 7 archive at the Earth Resources Observation System (EROS) Data Center DAAC has accumulated nearly 17 terabytes (more than 30,000 Landsat 7 images) in the 4 months since the instrument was turned on in July 1999.

- **Increase the number of distinct customers by 20 percent compared to FY 1997 (699,000 distinct customers).**

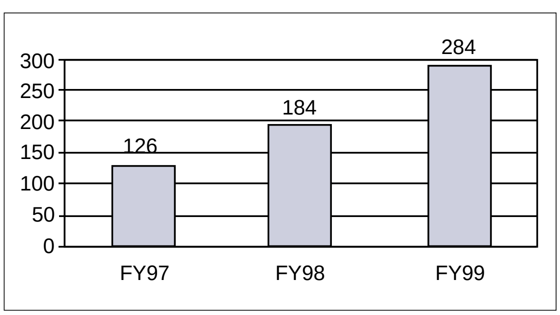


Figure 19. Data Volume by DAAC's

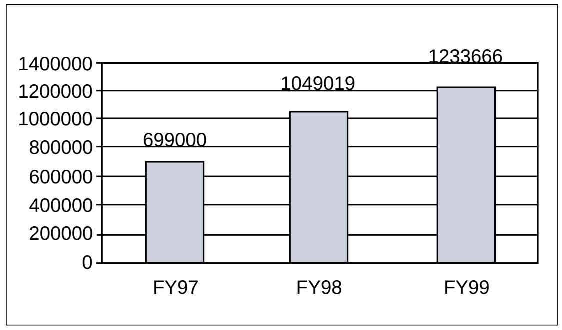


Figure 20. Number of DAAC Users

Target achieved: For FY 1999, 1,233,666 distinct users drew data from the DAAC's. This is a 77-percent increase over the 699,000 distinct users accessing the system in FY 1997, far exceeding the objective of increasing the number of users by 20 percent (Figure 20). The number of distinct users is expected to continue to grow through FY 2000 as EOSDIS realizes the widespread interest and demand for data products from the Terra mission.

- **Increase products delivered from the Distributed Active Archive Centers by 10 percent compared to FY 1997 (3,171,000 data products).**

Target achieved: During FY 1999, the EOSDIS DAAC's delivered 5,783,425 media or electronically delivered data products. Data product deliveries showed an 82-percent increase over the FY 1997 figure of 3,171,000, well over our target of a 10-percent increase over 1997 (Figure 21). This large increase was achieved despite the delay of Terra launch. The large increase can be explained primarily by the growth in World Wide Web delivery mechanisms.

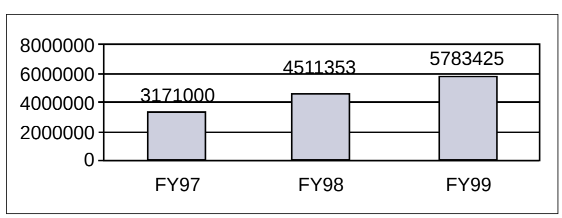


Figure 21. Data Products

Objective: Increase public understanding of Earth system science through education and outreach

Earth Science Enterprise missions and research programs make a unique contribution to education and the public understanding of Earth science. Just as the Enterprise has led the development of the new interdisciplinary field of Earth system science, so has it played a leadership role in infusing the Earth system science content into Earth science education. The performance targets were to:

- **Award 50 new graduate student/education research grants and 20 early career postdoctoral fellowships in Earth science.**

Target achieved: The Earth Science Enterprise awarded 50 new graduate student fellowships and 17 early career research grants during FY 1999. The fellowships and grants train the next generation of Earth scientists and engineers, contributing to a workforce of interdisciplinary scientists to address the study of Earth as a system. These scientists and engineers will use remote-sensing knowledge and data in practical fields related to Earth and environmental sciences, as well as the effects of natural and human-induced changes on the global environment.

- **Conduct at least 300 workshops to train teachers in the use of Earth Science Enterprise education products.**

Target achieved: The Earth Science Enterprise conducted 350 workshops for approximately 11,373 teachers during FY 1999. The teachers use Earth system science concepts and applications in lesson plans and classroom activities to educate students about the effects of Earth science on the environment. State education systems infuse Earth system science approaches and program content into their State curriculum infrastructure. Educators use mission science and applications data to design new Earth system science-related courses to train the next generation of scientists, engineers, and educators in Earth system environmental science.

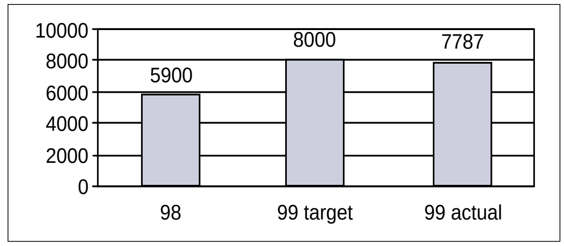


Figure 22. GLOBE Schools

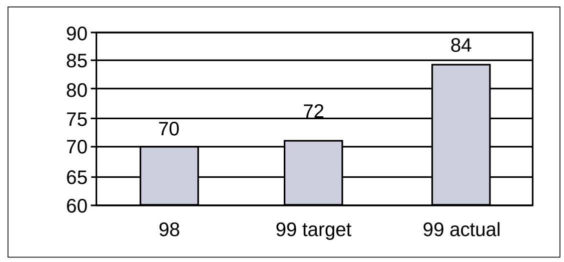


Figure 23. GLOBE Countries

- **Increase the number of schools participating in GLOBE to 8,000 from 5,900 in FY 1998, a 35-percent increase. Increase the number of participating countries to 72 from 70 in FY 1998.**

Target partially achieved: A total of 7,767 schools participated in GLOBE activities, a 29-percent increase from the 5,900 schools participating in 1998, and 84 countries participated, a 20-percent increase from the 70 countries participating in 1998.

Goal: Enable the productive use of Earth science and technology in the public and private sectors

The Earth Science Enterprise is making sure its data and associated information and knowledge lead to practical solutions for business and local governments. The Enterprise established 29 partnerships of various types to develop applications of Earth remote-sensing data for agriculture, natural resources management, urban and regional planning, and disaster mitigation. More than 100 partnerships with a variety of commercial firms help them use remote-sensing data to develop or improve their products and services. Enterprise researchers contributed to

four national and international scientific assessments of the environment to provide policymakers with an objective basis for decisionmaking.

Objective: Develop and transfer advanced remote-sensing technology

In collaboration with partners in industry and academia, the Earth Science Enterprise has developed and demonstrated new technologies of value to remote-sensing research. These technologies are the key to reducing by 30 percent the per-mission cost of post-2002 satellite missions compared to the EOS first series. The Enterprise's advanced technology development will also accelerate the growth of the U.S. remote-sensing industry by demonstrating smaller, more capable sensors. The performance targets were to:

- **Demonstrate a new capability to double the calibration quality for moderate-resolution land imagery.**

Target achieved: The MODIS preflight instrument was tested and integrated on the Terra spacecraft. The prelaunch calibration and characterization of MODIS protoflight instrument confirmed significant improvements in absolute calibration accuracy of moderate-resolution land imagery. The intercalibration activities carried out by MODIS teams in cooperation with the National Institute of Standards and Technology (NIST) established an absolute radiometric accuracy of better than 5 percent, which is consistent with the target of doubling the calibration quality.

- **Transfer at least one technology development to a commercial entity for operational use.**

Target achieved: As a result of the investment in our sensors and detectors technology development, Fibertek is now investing in nonpressurized laser designs that are less prone to failure and improve the company's profitability. In a second example of technology transfer, we are in the process of negotiating a Space Act partnership with Swales to transfer the SMEX Lite Spacecraft Architecture and related technologies. This was an open competition that Swales won. The purpose of this technology transfer partnership is to transfer the SMEX Lite Spacecraft Architecture to a U.S. private-sector company. It is intended that private companies, as a result of this transfer, will have the capability to design, fabricate, and operate spacecraft based on this architecture.

- **Advance at least 25 percent of funded instrument technology developments one Technology Readiness Level (TRL) to enable future science missions and reduce their total cost.**

Target achieved: We advanced 26 percent of funded instrument technology developments one Technology Readiness Level (TRL)—that is, 7 of 27 incubator Principal Investigators have advanced one TRL this year.

Objective: Extend the use of Earth Science Enterprise research for national, State, and local applications

The Earth Science Enterprise has initiated an extensive and varied dialog with State and local government organizations to identify their concerns that can be addressed with geospatial information resulting from Enterprise programs. We have created a variety of mechanisms by which partnerships of end users and scientists are brought together to create new solutions for local challenges in agriculture, natural resource management, disaster mitigation, and regional planning. The performance targets were to:

- **Establish at least five new Regional Earth Science Applications Centers.**

Target achieved: The Earth Science Enterprise selected nine proposals that were integrated into seven Regional Earth Science Applications Centers (RESAC). The RESAC's will produce and apply products derived from remotely sensed data to problems of regional significance and conduct region-specific assessments. Teams of universities, government agencies, and commercial partners will develop self-sufficient centers that make newly developed products available to a wide user community.

- **Establish at least eight new projects, with the U.S. Department of Agriculture, in the areas of vegetation mapping and monitoring, risk and damage assessment, and resource management and precision agriculture.**

Target achieved: The Earth Science Enterprise and the U.S. Department of Agriculture (USDA) jointly initiated 13 new projects to develop and demonstrate original and improved applications. The Earth Science Applications Research Program and USDA will also partner on three pilot projects leveraging the existing Land Grant and Space Grant networks into a cooperative NASA Earth Science Enterprise/USDA Cooperative Extension Service Strategic Alliance in Geospatial Information Technology. This alliance will use remote-sensing, Geographic Information System (GIS), and GPS technology to improve the traditional university extension activities for farmers.

- **Complete solicitation for at least seven cooperative agreements with State and local governments in land-use planning, land capability analysis, critical areas management, and water resources management.**

Target achieved: The Earth Science Enterprise established 11 agreements (4 cooperative agreements and 7 grants) with State and local governments. These projects involve approximately 20 State agencies, 15 regional/county-level agencies, and 12 States. The research conducted is generally led by university scientists partnering with regional, State, and local agency partners to develop improved resource management techniques. These demonstration projects will foster a shift from using Enterprise data and information for basic science to operational resource management.

Objective: Support the development of a robust commercial remote-sensing industry

NASA has been successful and committed to providing technical assistance and advice to companies developing the commercial remote-sensing market opportunities. The Commercial Remote Sensing Program is responsive to its mission and the remote-sensing industry through implementing programs that include the Earth Observations Commercial Applications Program (EOCAP), Affiliated Research Centers, and the Science Data Purchase. The performance target was to:

- **Establish at least 75 commercial partnerships in "value-added" remote-sensing product development, an increase from 37 (100 percent) over FY 1997.**

Target achieved: More than 100 partnerships were established in FY 1999 in the areas of education, environmental quality, food and fiber, health and safety, natural hazards, natural resources, and urban infrastructure. These partnerships will demonstrate how tangible services and products that will benefit society could be generated. Examples range from maximizing the capacity of waste disposal sites to assisting homeowners, civil defense, and insurance companies to lessen the loss of property caused by wildfires.

Objective: Make major scientific contributions to national and international environmental assessments

Because of the nature of the discipline, it is vital that Earth Science Enterprise research be conducted through cooperation and partnerships with other agencies and with other countries. The Enterprise has continued to contribute scientific knowledge and observations and modeling results to national and international scientific environmental assessments. The performance targets were to make significant contributions to two national and two international scientific assessments, including:

- **Atmospheric Effects of Aviation, in collaboration with the Federal Aviation Administration. The contributed model results of the climate effects of measured aircraft emissions will be provided to the Intergovernmental Panel on Climate Change (IPCC).**

Target achieved: The assessment has been completed and published.

- **U.S. regional/national assessment(s) in partnership with U.S. Global Climate Research Program (USGCRP) agencies.**

Target achieved: The Earth Science Enterprise sponsored a Native Lands/Native Peoples workshop in New Mexico on climate change impacts specific to the Native Lands. Results from this and three other Enterprise-sponsored global change assessments (in the Southeast, Southwest, and Upper Plains States regions) contributed to the understanding and impacts of climate variations on regional-specific natural resources and provided information to the Federal Advisory Committee for the Report to Congress on the National Assessments scheduled for completion in mid–FY 2000. The Enterprise also contributed to planning documents for the post-2000 USGCRP assessment activities.

- **Make significant contributions to the World Meteorological Organization (WMO) Ozone Assessment by providing a lead chapter author and most of the global-scale data.**

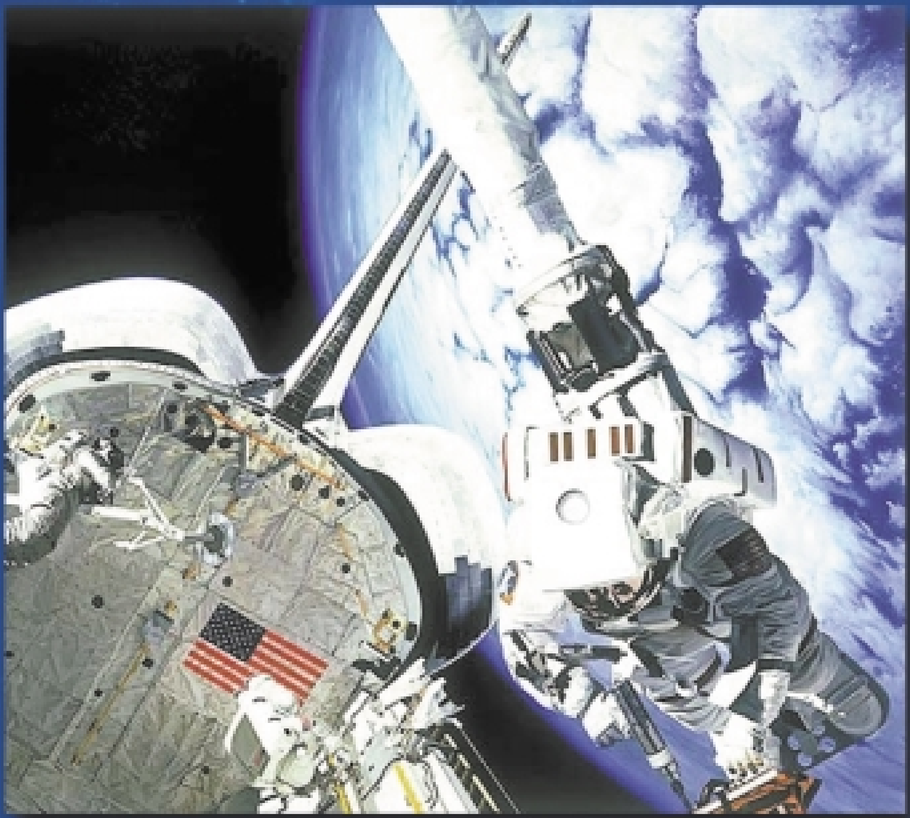
Target achieved: The Earth Science Enterprise provided global-scale data for WMO's "Scientific Assessment of Ozone Depletion: 1998, World Meteorological Organization, Global Ozone Research and Monitoring Project Report No. 44," which was published in late FY 1999.

- **Provide a lead chapter author, global-scale data, and researchers to the IPCC Assessment Report, sponsored by United Nations Environment Programme and WMO.**

Target achieved: One of the NASA-sponsored scientists authored Chapter 4, "Atmospheric Chemistry and Radiative Trace Gases," of the report, and other NASA-sponsored researchers also contributed to this and other chapters of the report. The first draft will be reviewed by agencies and the scientific community during early FY 2000, and three working group assessments and an overview are scheduled for completion and release by early FY 2001.

Earth Science Data Validation and Verification

The Earth Science Enterprise holds each of the program and project managers fully accountable for the accuracy of the performance information that is duly reported through the normal management and reporting processes. A review of the progress against each of the targets has been incorporated into management reviews at all levels within the Earth Science Enterprise organizations.



"Working in Space," oil by Linda Draper shows astronauts performing extravehicular activities (EVA) around the Shuttle's cargo bay area.

Human Exploration and Development of Space Enterprise

Strategic Goals and Objectives

The Human Exploration and Development of Space (HEDS) Enterprise seeks to expand the frontiers of space and knowledge by exploring, using, and enabling the development of space for human enterprise. HEDS pursues the following long-term goals to achieve this mission:

- Explore the role of gravity in physical, chemical, and biological processes
- Continue to open and develop the space frontier
- Prepare to conduct human missions of exploration
- Aggressively seek investment from the private sector

In FY 1999, HEDS began assembling the International Space Station (ISS). The U.S. owned, Russian-built Zarya Functional Cargo Block was delivered to orbit in November 1998, and the U.S.-built Unity Node followed 2 weeks later. At the close of fiscal year 1999, the ISS was approaching 10 months of service with most on-orbit systems operating at or above design specifications. On the ground, the program continued to deliver all major flight hardware to the launch site at Kennedy Space Center.

HEDS supported four Space Shuttle launches in FY 1999 while accomplishing several important improvement milestones for the Shuttle fleet. STS-95 carried a pressurized module for conducting laboratory research as its primary payload. STS-88 delivered the Unity Node of the ISS to orbit, and STS-96 delivered supplies and conducted a checkout of the ISS in orbit. Finally, STS-93 launched and deployed the Chandra X-ray Observatory, the heaviest payload in the history of the Space Shuttle program.

HEDS released five NASA Research Announcements (NRA) and built its investigator community to 872 investigations (a 9-percent increase over 1998) as part of continuing preparations for ISS utilization. In addition to regular releases of NRA's, HEDS is breaking new ground by selecting research in Biologically Inspired Technology through a dedicated NRA

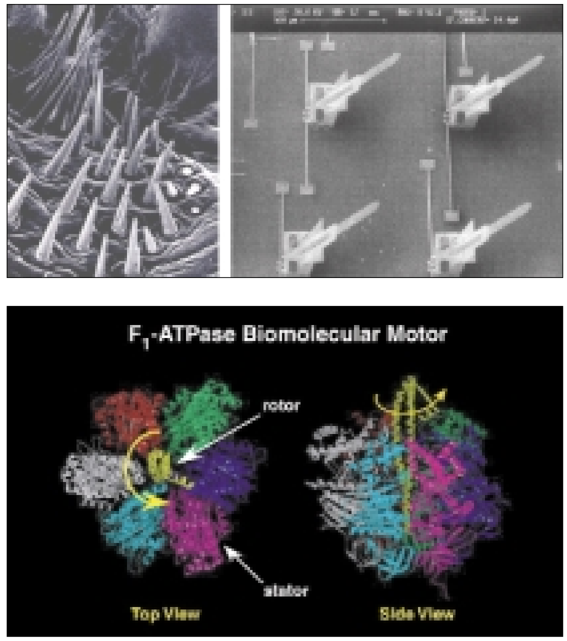


Figure 24. Examples of Biology-Inspired Technology Research—Micromachined Hair Cell Sensors (top) and Biomolecular Motors (bottom)

(Figure 24). As noted above, FY 1999 included the flight of STS-95, a Space Shuttle research mission to conduct research in the life and microgravity sciences, including some exploratory research on aging and space flight. HEDS researchers convened to conduct a 1-year postflight review of results from the Neurolab Space Shuttle mission, and preparations continued for STS-107, the next major Space Shuttle research opportunity.

HEDS researchers in the life and microgravity sciences received 40 patents and published more than 1,900 articles in peer-reviewed journals in FY 1998 (FY 1999 statistics are currently being tabulated). Commercial interest in life and microgravity research remained strong as cash and in-kind investments by the private sector increased to over $50 million with substantial commercial participation on STS-95.

HEDS completed a Critical Design Review of experiments planned for the Space Science Enterprise's Mars 2001 Lander mission and released an NRA to solicit proposals for future landers in 2003 and 2005.

Performance Measures

HEDS met 32 of its 37 performance targets by the end of FY 1999. Of the five targets not achieved, three were partially achieved. It is anticipated that two will be completed by the end of FY 2000. A third resulted from remanifesting the launch of the Window Observation Research Facility from the first to the second utilization flight. The final target, an 85-percent on-time launch record, was not achieved because of the priority placed on safety.

Goal: Explore the role of gravity in physical, chemical, and biological processes

Objective: Enable the research community to use gravity as an experimental variable

HEDS seeks to take advantage of the microgravity environment to pursue research questions in biology, chemistry, physics, and technology. Microgravity enables groundbreaking new research in systems ranging from cells to flames. In FY 1999, the HEDS Office of Life and Microgravity Sciences and Applications (OLMSA) concentrated on taking advantage of available opportunities during ISS assembly to develop and prepare the scientific community for the era of ISS research. Despite difficult budget constraints, HEDS has increased the number of investigations it supports by 9 percent without significantly reducing the average size of grants awarded.

All scientific research within HEDS is selected through an open and competitive peer review process. The health of our research community is indicated by strong responses to NASA research announcements leading to selection rates of about 20 percent of proposals received. As noted above, HEDS researchers published more than 1,900 articles in peer-reviewed journals in FY 1998. A similar level of publication is expected for FY 1999. Funding for OLMSA was $214 million in FY 1998, so the gross ratio of budget to publications was about $113,000 per publication (Figure 25).

Figure 25. Journal Covers Featuring FY 1999 HEDS Research

HEDS researchers produced a number of important findings in FY 1999. Among the highlights in the physical sciences are new findings in fluid physics based on a colloidal system of hard spheres used to model materials structures. When carried to orbit, this classic model system has displayed new and unanticipated properties, and these findings may lead to a better understanding of materials formation. In microgravity, the system shows a dendritic growth pattern that is similar to growth patterns of crystals in solidifying metal on Earth. Because these growth patterns play a major role in determining properties such as strength and flexibility in metals, new models for predicting and describing this process may lead to improved industrial processes and higher quality products.

In biotechnology, researchers have documented the surprisingly strong effect that gravity has on the expression of genes. An experiment produced substantial and unexpected differences in gene expression between flight and ground cell culture samples.

As recent events on the Russian *Mir* space station have shown, spacecraft fire safety is critical for long-duration space flight. Spacecraft fire safety data were verified through cooperative U.S.-Russian *Mir* experiments. The flammability of selected U.S.-supplied plastic materials was tested under microgravity conditions in a Russian-supplied combustion tunnel operated on the *Mir* Orbital Station. The data were compared to reference testing of the flammability, heat release, thermal properties, and combustion products of identical materials in ground laboratories at both the Russian Keldysh Research Center and the NASA Johnson Space Center's White Sands Test Facility.

In summary, HEDS continues to develop an outstanding science research community for the ISS, while at the same time taking advantage of available research opportunities to conduct an outstanding program of peer-reviewed research. Specific targets and results are reported below with references and abstracts as appropriate. Please note that more results of interest obtained by commercial researchers are reported under another HEDS goal: "Aggressively seek investment from the private sector." The performance targets were to:

- **Support an expanded research program of approximately 800 investigations, an increase of approximately 9 percent over FY 1998.**

Target achieved: The HEDS Enterprise supported 872 investigations.

- **Publish 90 percent of FY 1998 science research progress in the annual OLMSA Life Sciences and Microgravity Research Program Task Bibliographies and make it available on the Internet.**

Target achieved: Of FY 1998 research tasks, 97 percent are described in current progress reports posted on the Internet.

- **Establish a National Center for Evolutionary Biology with participation of at least 5 research institutions and engaging at least 20 investigators.**

Target partially achieved: FY 1999 activities have met the intent of the FY 1999 performance target. Evolutionary Biology proposals were solicited in the 98-HEDS-02 NRA as part of the Gravitational Biology and Ecology program's annual call for research proposals. A total of 20 proposals were received for review in FY 1999. Nine proposals were selected for funding. The 9 proposals engage 6 institutions and involve the participation of 14 investigators. On August 3, 1999, an initial meeting of the nine Principal Investigators was held to discuss forming a consortium among the funded investigations. The selection of proposals for funding was based on the quality of proposals received. The decision was made to fund only proposals that were of sufficient quality to enhance this activity.

- **Publish a report of comparison of three different biological models to understand the influence of gravity on the nervous system.**

Target achieved: The influence of gravity on the nervous system was studied in three biological models on the Neurolab mission (STS-90, April 17–May 3, 1998) with data analysis, interpretation, and preparation of reports ongoing during FY 1999. The three models were (1) human central and peripheral nervous systems, (2) central nervous system of young and adult rodents, and (3) vestibular nerve of the teleost toadfish, *opsanus tau*. One publication has appeared in print. Other publications are in process. The preliminary results were presented by the investigators at the National Academy of Sciences during the Neurolab One-year Postflight Symposium (April 14–16, 1999) and were recently published in *Current Opinion in Neurobiology* (S.M. Highstein and B. Cohen, 1999, vol. 9: pp. 495–499). Abstracts of results presented at the 29th annual Society for Neuroscience meeting (October 23–28, 1999) included:

- N.L. Hayes and R.S. Nowakowski, UMDNJ–Robert Wood Johnson Medical School. Cell proliferation, nucleotide metabolism, and cell death in the developing telencephalon are affected by space flight. (abstract #102.17)
- C.A. Fuller, D.M. Murakami, T.M. Hoban-Higgins, P.M. Fuller, and D.E. Woolley, University of California, Davis. Effects of space flight on the regulation of the rat circadian timing system. (abstract #349.13)
- M.D. Temple, K.S. Kosik, and O. Steward, University of Virginia and Harvard University. Spatial navigation and memory of place in animals that develop in microgravity. (abstract #649.10)
- J.J. Knierim, B.L. McNaughton, and G.R. Poe, University of Texas–Houston Medical School and University of Arizona. Three-dimensional spatial selectivity of hippocampal neurons during space flight. (abstract #864.18)

■ **Publish a report defining the time course adaptations in the balance system to altered gravitational environments.**

Target achieved: Numerous publications have appeared during FY 1999 that summarize the results of experiments conducted during short-duration (up to 16 days) or long-duration (up to 188 days) space flight. Key findings include:

- Studies found that the recovery of sensorimotor postural control after orbital space flight in Shuttle crewmembers strongly implicates disrupted processing of otolith inputs as the source of postural instability upon return from orbital flight. (*J Vestibular Res* (1999): in press)
- Investigators quantified significant multivariate changes in multijoint coordination in astronauts after space flight, consistent with reweighting of vestibular inputs and changes in control strategy in a multivariable control system. (*J Biomech* 31 (1998): 883–889)
- In an extensive review of published results, investigators have determined that correct transduction and integration of signals from all sensory systems is essential to maintaining stable vision, postural and locomotor control, and eye-hand coordination as components of spatial orientation. (*Brain Res Rev* 28 (1998): 102–117).

■ **Document *Mir* data lessons learned to facilitate ISS biomedical and countermeasure research.**

Target achieved: Lessons learned are documented in the "Report of Medical Operations Summit Meeting on NASA/Mir Program From August 4–5, 1998." Payloads utilization lessons learned have been documented in the Phase 1 Lessons-Learned Database and applied in the implementation of the Biomedical Research and Countermeasures program ISS payloads. NRA solicitation/selections have been adjusted based on lessons learned, incorporating lessons learned in payload utilization, support planning and experiment manifesting, and technology development of experiments.

Numerous publications in the areas of nutrition, metabolism, musculoskeletal physiology, and behavior/performance have appeared during FY 1998 summarizing the results of experiments conducted during Shuttle-*Mir* experiments (up to 188 days). Published and yet-to-be-published lessons learned have been incorporated in all aspects of the Biomedical Research and Countermeasures program. Key findings include the following:

- Investigators determined that energy intake, weight, and protein synthesis were decreased during flight, suggesting the need for dietary strategies for long-duration space flight. (*Am J Physiol* 276 (1999): E1014–21)
- Investigators found that during flight, subjects lost up to 250 milligrams of bone calcium per day and regained bone calcium at a slower rate of about 100 milligrams per day for up to 3 months after landing. (*Amer J Physiol-Reg Integ & Comp Physiol* 46 (1999): R1–R10)
- Investigators reviewed endocrine data from Skylab on and related them to body composition. They suggest that a combination of measures, including exercise, diet, and drugs, is required to ensure muscle health for extended space flight. (*Nutr Res* 18 (1998): 1923–1934)
- Investigators documented psychiatric issues (adjustment and psychosomatic reactions, asthenia, mood and thought disorders, and postmission personality changes and family problems) during long-duration flight. (*Aviat Space & Environm Med* 69 (1998): 1211–1216)

■ **Document *Mir* data lessons learned to facilitate ISS research in fundamental biology and regenerative life support.**

Target achieved: Fundamental biology experiments in the following discipline areas were conducted as part of the Phase 1 NASA/Mir program: avian developmental biology, plant biology, circadian rhythm research, and radiation monitoring:

- The *Mir* experience clearly demonstrated the need for measurement and/or control of ethylene during future plant experiments.

- *Mir* in-flight data must be considered in the design of flight hardware for a plant experiment to be successful.
- New methods of fixation and or better fixatives are needed for future avian experiments.

FY 1999 activities have met the intent of the FY 1999 performance target. Ethylene removal equipment is being incorporated into the design of plant hardware in development. The Gravitational Biology and Ecology program office has signed an agreement with the ISS environmental monitoring group to analyze gas sampled on the ISS for ethylene content throughout the assembly process and to distribute those data. Developmental prototypes of plant growth and avian development hardware are being flown to test the design of critical subsystems, including soil moisture distribution systems in the plant growth unit and egg fixation systems in the avian development unit. Both of these hardware developers have consultants with Phase 1 experience working on their projects. Personnel with Phase 1 experience have also been placed in key positions involved in ISS planning to ensure that *Mir* lessons learned are considered as we develop experiments for the ISS.

■ **Analyze *Mir* data to achieve a 3-year jump-start for cell culture and protein crystal growth research and document analyses and lessons learned.**

Target achieved: The NASA-*Mir* program served as a testbed for the ISS biotechnology research facility and research approaches. Several problems were identified and documented via lessons learned. If these problems and procedures had not been identified until the ISS, the flight hardware and facility would have to have been returned to Earth, redesigned, and redeployed, wasting a large amount of valuable research time on the ISS. These hardware redesigns, coupled with changes in research procedures, could have resulted in significant delays in implementing this research.

The Biotechnology Cell Science program was able to assess the impact of the space environment on data acquisition and storage. The results are contained in a series of Phase 1 reports. The operation of cell science hardware in long-duration space flight resulted in numerous modifications for bubble control and the development of a new (patent pending) bioreactor that enables routine bubble management.

In preparation for protein crystal growth on the ISS, the *Mir* program served as an important proving ground to develop passive crystal growth techniques that required minimal crew involvement and an early opportunity to verify long-duration performance. Data from the experiments that were performed on *Mir* has been invaluable in contributing toward the optimizing of solution conditions and controlling configurations of units for selected proteins and precipitants. These data are critical to the successful and timely planning for later experiments on the ISS program.

A summary of this work in the *Mir* Phase 1 report can be found on the World Wide Web at *http://www.hq.nasa.gov/office/olmsa/iss/Phase1.pdf.*

■ **Document *Mir* radiation research data to facilitate ISS extravehicular activity (EVA) planning.**

Target achieved: Using the tissue equivalent proportional counter (TEPC), NASA researchers were able to improve models for predicting the radiation environment on orbit. Specific findings include the following:

- The drift rate of the South Atlantic Anomaly (an area of higher radiation exposure) was established.
- A relationship with galactic cosmic radiation dose rate with deceleration potential was developed that provides future estimates of absorbed dose rate to ±15 percent.
- The trapped particle dose rate is quadratically related to the atmospheric density estimated nearly a year earlier.

Recent findings have been reported at the 3rd Phase 1 Workshop in Huntsville, Alabama (November 1998), the First Biennial Space Biomedical Investigators Workshop in Houston (January 1999), and the Annual Radiation Health Investigator's Workshop in Upton, New York (April 1999).

- **Improve predictive capabilities of soot processes by at least 50 percent through analysis of MSL-1 data, and publish results in peer-reviewed open literature.**

Target achieved: The following peer-reviewed publications report improved predictive capability in excess of 50 percent:

- Xu, Lin, and Faeth. *Combustion and Flame* 115 (1998): 195–209
- Lin, Faeth, Sunderland, Urban, and Yuan. *Combustion and Flame* 116 (1999): 415–431
- Urban, Yuan, Sunderland, Linteris, Voss, Lin, Dai, Sun and Faeth, *AIAA Journal* 36 (1998): 1346–1360

Researchers focused on two submodels: rate of soot growth and predicted flame shape. The prediction of the rate of soot growth depends on validating a specific mechanism, the so-called hydrogen-abstraction/carbon-addition (HACA) mechanism. Prior to this work, submodels using this HACA mechanism underpredicted soot growth rates by as much as a factor of 3. From the Laminar Soot Processes Experiment on the first Microgravity Science Laboratory (MSL-1) and its associated ground-based program, new exemplary data were obtained that enabled the model of the HACA mechanism to be sharply corrected. Rather than a factor of 3 underprediction, the submodel is now within approximately plus or minus 25 percent. This constitutes better than the goal of a 50-percent improvement in our ability to predict flame-associated soot levels. With the second submodel, we now obtain successful prediction of the flame shapes of closed-tip flames in still air to within 10 percent—a necessary step toward the establishment of a robust state relationship.

- **Use MSL-1 results to eliminate one of the three primary fluid flow regimes from consideration by casting engineers, and publish this result in peer-reviewed literature. Casting engineers may use this information to improve metal casting processes in industry.**

Target achieved: As a result of experiments on MSL-1, it has unequivocally been shown that there are no fluid flow effects on the nucleation of solids from the melt in the flow regime where liquid flows are laminar. Hence, the performance target was achieved. Two papers addressing the fluid effects have been published in peer-reviewed journals:

- W.H. Hofmeister, R.J. Bayuzick, R. Hyers, and G. Trapaga. “Cavitation-induced Nucleation of Zirconium in Low Earth Orbit,” *Appl Phys Lett* 74(18) (1999)
- C.M. Morton, W.H. Hofmeister, R.J. Bayuzick, A.J. Rulison, and J.L. Watkins. “The Kinetics of Solid Nucleation in Zirconium,” *Acta Mater* 46(17) (1998)

- **Use data obtained by fluid physics experiments on suspensions of colloidal particles on MSL-1 to answer fundamental questions in condensed matter physics regarding the transition between liquid and solid phases, and publish data on the transition from liquids to solids and the results in peer-reviewed open literature.**

Target achieved: Hard sphere colloidal systems are used as a model for studying the structure of and transition between liquids, crystals, and glasses. The MSL-1 investigations seek to obtain a complete understanding of the transition between liquid and solid phases in hard sphere colloidal dispersions. The investigations answer the following fundamental questions:

1. How does gravity affect nucleation and growth of the crystals?

   Gravity significantly affects nucleation, growth, and ripening (development) of colloidal crystals. Colloidal crystals grown in the microgravity environment show an initially predominant random hexagonal closed packed (rhcp) structure, but face centered cubic (fcc) structures emerge at long times. In normal gravity, they start out as a mixture of fcc and rhcp. Theory predicts fcc as the preferred structure; the MSL-1 low-gravity experiments have provided an unique validation.

2. How does the viscosity of the material change across the transitions from fluid to crystal to glass?

   MSL-1 data show that the shear modulus of the crystalline phases conforms to expectations from computer simulations.

3. What is the rigidity of the crystalline phase?

   The dynamics of crystal growth displays many features expected from theory, with evidence of simultaneous growth and coarsening as well as dendritic growth. Dendritic growth is rarely observed in Earth's gravitational environment because buoyancy-driven settling destroys the weak dendritic structure. The morphology (type of structure) of the crystalline phase determines the structural properties of the material. Microgravity, therefore, provided a truly unique window to study such structure and instabilities giving rise to them (Figure 26).

Figure 26. Colloidal Crystals in 1g (left) and in Space (right)

The following papers that appear in the peer reviewed literature report the findings described above:

- C.T. Lant, A.E. Smart, D.S. Cannell, W.V. Meyer, and M.P. Doherty. "Physics of Hard Spheres Experiment: A General Purpose Light Scattering Instrument," *Applied Optics* 36 (1997): 7501–7507 (appeared on the cover of *Applied Optics*)
- W.B. Russell, J. Zhu, M. Li, R. Rogers, W.V. Meyer, R.H. Ottewill, Crew Space Shuttle *Columbia*, and P.M. Chaikin. "Crystallization of Hard Sphere Colloids in Microgravity," *Nature* 387 (1997): 883–885
- W.B. Russell, J. Zhu, R. Rogers, W.V. Meyer, and P.M. Chaikin. "Dendritic Growth of Hard Sphere Crystals," *Langmuir* 13 (1997): 3871–3881
- W.B. Russell and A.P. Gast. "Simple Ordering in Complex Fluids," *Physics Today* (December 1998): 24–30 (appeared on the cover of *Physics Today*)
- W.B. Russell, S.-E. Phan, M. Li, J. Zhu, P.M. Chaikin, and C.T. Lant. "Linear Viscoelasticity of Hard Sphere Colloidal Crystals from Resonance Detected with Dynamic Light Scattering," *Physical Review* 60 (1999): 1988–1998

Goal: Continue to open and develop the space frontier; develop and assemble the ISS and utilize it to advance scientific, exploration, engineering, and commercial activities; and provide safe and affordable human access to space

Objective: Improve Space Shuttle program operations by safely flying the manifest and aggressively pursuing a systems upgrade program

The Space Shuttle program provided outstanding customer support to four Space Shuttle missions and accomplished several high-visibility milestones for the Shuttle Upgrade program during the FY 1999 time period. The four missions were:

- The STS-95 flight was launched on October 29, 1998, and successfully completed an 8-day, 21-hour mission. Some mission records included: the first flight of three Block IIA main engines, the first flight test using space-to-space communications, the second flight of the Super Lightweight Tank, and Senator John Glenn's first Space Shuttle mission as the oldest astronaut to fly at 77 years and 4 months. Payloads included a SPACEHAB double module and the release and capture of a SPARTAN payload.
- The second mission of FY 1999 was STS-88, the first U.S. launch of ISS hardware, the Unity Node. The mission was launched on December 4, 1998, and successfully completed an 11-day, 19-hour mission. The crew deployed the ISS Unity Node and mated it to the Russian launched Zarya module.
- The third mission of FY 1999 was STS-96, a 9-day, 19-hour supply and checkout mission to the ISS, launched on May 27, 1999 (Figure 27). All mission objectives were successfully completed.

Figure 27. STS-96 Launch

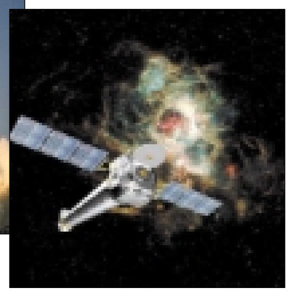


Figure 28. Chandra X-ray Observatory

- The last mission of FY 1999 was STS-93, the launch and deployment of NASA's third Great Observatory, the Chandra X-ray Observatory (Figure 28). This launch occurred on July 23, 1999. Chandra was designed to observe x-rays from high-energy regions of the universe, such as hot gas in the remnants of exploded stars. This nearly 50,000-pound payload was the heaviest payload ever launched by a Space Shuttle. This mission was also the first flight of a female commander, Eileen Collins. The mission successfully completed all of its objectives during the 4-day, 22-hour flight.

During STS-93 mission ascent, a voltage drop in the main engine controller digital computer unit was observed. The backup unit immediately came on line, and the mission proceeded without incident. During postflight inspection, it was determined that a short circuit had occurred between an exposed wire and a screw head. This situation resulted in a thorough inspection and repair, where required, for all the Space Shuttle orbiters.

During FY 1999, the Space Shuttle Upgrade program accomplished many significant improvement milestones for the Shuttle fleet. Among the most notable accomplishments were:

- The delivery of OV-104 (*Atlantis*) to Kennedy Space Center following its Orbiter Maintenance Down Period. During this time, the orbiter was upgraded with a "glass" cockpit. This orbiter is scheduled to fly early in calendar year 2000.
- The continued development of the Checkout and Launch Control System, now scheduled for completion in November 2002. This new system, designed and being built "in-house," will replace Shuttle control room systems with state-of-the-art commercial equipment and software, thereby assuring that sound, safe and efficient practices and processes are in-place for privatized/commercialized launch site processing.
- The continued development of the high-pressure fuel turbopump. In FY 1999, the problems with housing cracks and vibration anomalies were resolved, and the program is now into certification testing and on track for first flight in mid FY 2000.

■ **Achieve seven or fewer flight anomalies per mission.**

Target achieved: We observed an average orbiter in-flight anomaly rate of 4.75 (Figure 29)

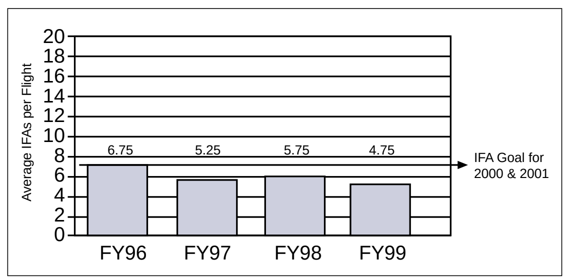


Figure 29. Shuttle Anomalies

■ **Achieve 85 percent on-time, successful launches (excluding the risk of weather).**

Target not achieved: We observed a 67-percent on-time launch rate (Figure 30).

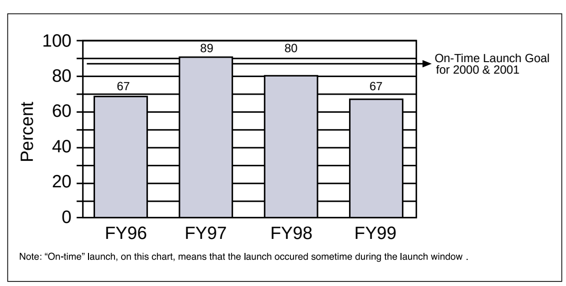


Figure 30. Shuttle On-Time Launch Rate

Launch scrubs/delays were called to assure a safe launch and the successful completion of the mission. So, while NASA failed to meet this specific performance target, the Agency did meet the requirements and intent of the strategic objective, which is to fly each mission safely. The specific scrub history for FY 1999, excluding weather-related scrubs, is summarized below:

STS-95	No technical/operations scrubs
STS-88	One scrub for anomaly resolution of an unexpected master alarm associated with hydraulic system 1
STS-96	No technical/operations scrubs
STS-93	One scrub, which resulted from an anomalous report of hydrogen concentration in the aft compartment exceeding launch commit criteria

- **Achieve a 13-month flight manifest preparation time.**

Target achieved: NASA achieved a 12-month flight preparation cycle (manifest template) (Figure 31).

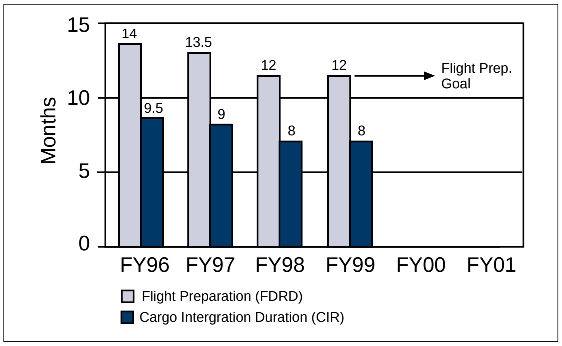


Figure 31. Shuttle Flight Preparation Time

- **Achieve a 60-percent increase in predicted reliability of the Space Shuttle over 1995.**

Target achieved: We achieved a 60-percent increase in predicted reliability of the Space Shuttle over 1995—from 1/262 to 1/438 (median probability on ascent). These figures are calculated using a personal computer-based software tool known as the Quantitative Risk Assessment System (QRAS) for conducting quantitative risk assessment, together with a quantified Space Shuttle risk model. The combination of QRAS and the Shuttle risk model can be used to calculate the change in the probability of catastrophic failure of the Space Shuttle as the result of Shuttle upgrades. This process was used to calculate the probabilities of loss of the vehicle as the result of the various Space Shuttle Main Engine upgrades shown in Figure 32.

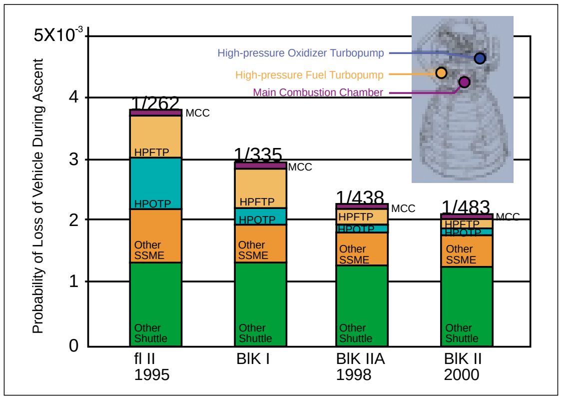


Figure 32. Shuttle Reliability

An evaluation of these models was conducted, with a report filed in January 2000. The Office of Safety and Mission Assurance is currently evaluating the report and continues to improve the models.

Objective: Deploy and operate the ISS for research, engineering, and exploration activities

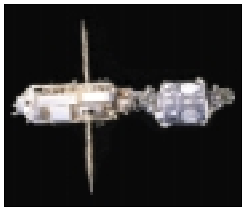


Figure 33. Zarya Mated With Unity

FY 1999 was a proud and successful year for the ISS program. The U.S.-owned, Russian-built Zarya Functional Cargo Block (FGB) was successfully launched and delivered to orbit on November 20, 1998. The U.S.-built Unity Node was launched 2 weeks later and mated with Zarya on December 6, 1998 (Figure 33). NASA also completed the first ISS logistics mission, in May 1999, delivering almost 2 tons of supplies and equipment that will be needed to operate and live on the ISS. At the close of fiscal year 1999, the on-orbit vehicle was approaching 10 months of service with most on-orbit

systems operating at or above design specifications. The ISS program had also successfully demonstrated its lead mission management responsibility, continuing the excellent level of cooperation between the United States and Russia established during the Shuttle-*Mir* program. While launching and maintaining on-orbit operations, the program continued to deliver all major flight hardware through Assembly Flight 8A, except for the Airlock, to the launch site at Kennedy Space Center. At the close of the fiscal year, the ISS prime contractor had completed over 86 percent of contracted tasks. The Canadian-built Space Station Remote Manipulator System (SSRMS) and two Italian-built Multi-Purpose Logistics Models (MPLM) have also be delivered to Kennedy. The program completed the early phases of the Multi-Element Integrated Test (MEIT) with several ISS elements to successfully demonstrate overall hardware and software compatibility. The Russian Service Module and Logistics Flight 2A.2 are at their respective launch sites in preparation for launch during calendar year 2000.

Although tremendous progress was made during FY 1999, several ongoing issues continued to constrain the program. Difficulties with the U.S. Laboratory Module development schedule, coupled with delays to the Russian Service Module caused by recent failures of the Proton launch system, have delayed planned assembly and expedition flights. ISS contingency planning includes near-term plans to augment Russian propulsion and logistics capabilities with the Space Shuttle and the preparation of the Interim Control Module for launch-on-need reboost and attitude control. Long-term plans include Shuttle orbiter modifications for additional reboost capability, the development of a permanent U.S. propulsion module, and the provision of six-crew return capability. The performance targets were to:

Figure 34. FGB

- **Deploy and activate the Russian-built FGB (Functional Cargo Block) as the early propulsion and control module.**

Target achieved: The U.S.-owned, Russian-built Zarya (FGB) was launched from the Baikonur Cosmodrome on November 20, 1998. With its successful delivery into orbit, Zarya was activated to checkout the early ISS on-orbit systems capabilities (Figure 34).

Figure 35. Zarya-Unity Mating

- **Deploy and activate the first U.S.-built element, Unity (Node 1), to provide docking locations and attach ports.**

Target achieved: Unity was launched from Kennedy Space Center on December 3, 1998. It was successfully delivered to orbit and docked and mated with Zarya on December 6, 1998. After 10 months of operations in orbit, most systems are continuing to operate at or above the design prediction. The communications systems among Houston, Moscow, and the on-orbit vehicle are functioning well (Figure 35).

- **Initiate full-scale Multi-Element Integration Testing (MEIT) for elements in the first four launch packages.**

Target achieved: Several MEIT test configurations for elements in the first four launch packages (including the U.S. Laboratory Module, the Canadian SSRMS, the first truss segments, and photovoltaic arrays and radiators) were initiated and completed between May and August 1999. While some regression testing remains, the tests demonstrated excellent overall hardware and software compatibility while identifying areas requiring additional work prior to flight.

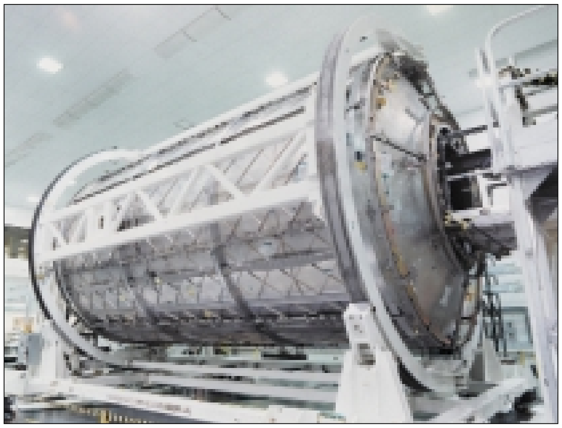


Figure 36. U.S. Laboratory Module

- **Deliver the U.S. laboratory module to the launch site in preparation for MEIT.**

Target achieved: The Laboratory Module was delivered to Kennedy Space Center during November 1998. It was successfully included in MEIT test configurations, which were initiated and completed between May and August 1999 (Figure 36).

- **Conduct physical integration of the Z1 Truss launch package and initiate MEIT.**

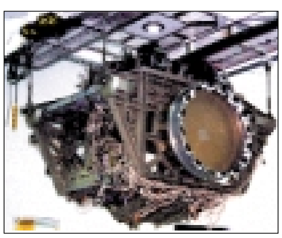


Figure 37. Z1 Truss

Target achieved: The Z1 Truss completed its physical integration during early calendar year 1999. It was successfully included in MEIT tests and initiated and completed between May and June 1999.

- **Initiate preparations for the launch of the first EXPRESS rack with five payloads on 7A.1**

Target achieved: The first two EXPRESS (Expedite the Processing of Experiments to Space Station) racks are completing their Fabrication/Assembly/Integration schedule milestones. The two EXPRESS racks are scheduled for delivery to Kennedy Space during early calendar year 2000. Both of the first two EXPRESS racks have been accelerated to launch on 6A. Seven payloads are currently baselined to launch with the EXPRESS racks.

- **Initiate preparations for the launch of the first rack of the Human Research Facility (HRF-1) and the Window Observation Research Facility (WORF-1) on the first Utilization Flight (UF-1).**

Target partially achieved: The first rack of the Human Research Facility (HRF-1) has completed its delta Critical Design Review (CDR). The flight rack was delivered to Johnson Space Center, and integration and testing are under way. HRF-1 has been accelerated to launch on 5A.1. While continuing in its early design and development phases, the WORF-1 has been remanifested to launch on UF-2. It has completed its Systems Requirements Review and Preliminary Design Review. During FY 2000, it will complete the Critical Design Review and initiate manufacturing/assembly. The WORF-1 will be delivered to Kennedy Space Center in mid-2001 to support a launch on UF-2, 4 months later than originally planned. This reprioritization will not require additional resources and will not affect the delivery schedules for other research facilities.

Objective: Ensure the health, safety, and performance of space flight crews

HEDS programs in Biomedical Research and Countermeasures (BR&C) and Advanced Human Support Technology produced important scientific and technology research results to improve the health safety and performance of space flight crews. Thirty investigator-initiated research proposals (26 new and 4 renewals) were chosen through NRA 98-HEDS-02. Proposals cover all discipline elements of the BR&C program: Physiology, Behavior and Performance, Environmental, Operational and Clinical, and Radiation Health research.

In collaboration with the National Institute on Aging, experiments exploring the parallels between the physiological changes associated with aging and space flight

were successfully flown on the STS-95 research mission (Figure 38). Seven biomedical experiments (including a test of potassium citrate as a countermeasure to kidney stone formation in space flight) were selected for the STS-107 research mission, scheduled for 2001. During FY 1999, BR&C flight investigations planned for the early ISS began a rapid development phase to enable their flight in the FY 1999–2001 timeframe.

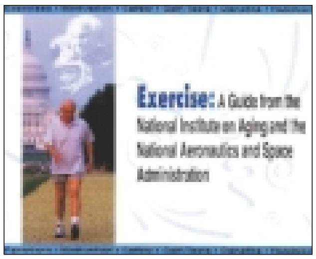


Figure 38. An Exercise Guide by the National Institute on Aging and NASA With John Glenn on the Cover

As part of a continuing effort in the application of NASA technologies to telemedicine, a Virtual Collaborative Clinic was held at NASA Ames Research Center on May 4, 1999. Physicians and technical staff at multiple remote sites interacted in real time with three-dimensional visualizations of patient-specific data using next-generation high-bandwidth networks. Participants were from the Cleveland Clinic, NASA's Glenn Research Center, the Northern Navajo Medical Service Center in Shiprock, New Mexico, Stanford University; Salinas Valley Memorial Hospital, the University of California at Santa Cruz, and NASA's Ames Research Center. Medical visualizations were a stereo reconstruction from a CT scan of a heart with a graft, stereo dynamic reconstructions (beating heart) of echocardiograms with Doppler effects, and three-dimensional virtual jaw surgery using our CyberScalpel for irregular-shaped or round bones and organs (Figure 39).

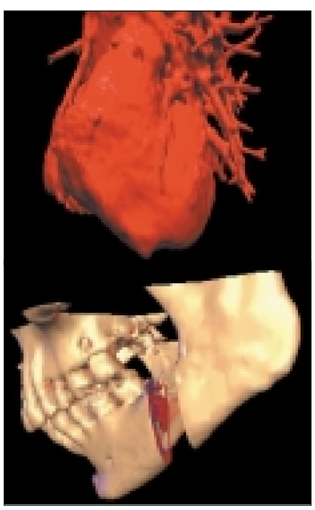


Figure 39. Virtual Reconstructions of the Heart (top) and Jaw Surgery (bottom)

The successful flight of the Electronic Nose Flight Experiment on STS-95 represents a major step forward in advanced sensor design. The electronic nose combines an array of conducting polymers with neural net computer technology to detect a broad array of chemicals in the air while consuming only minimal power and volume. The Space Shuttle flight test of a miniature quadrapole mass spectrometer to detect specific chemicals is currently manifested for STS-98 (ISS flight 5A) in April 2000.

HEDS partnered with industry to create a Food Technology Commercial Space Center, which will perform research that could lead to better food for astronauts and safer, more nutritious packaged foods for everyone. The performance targets were to:

- **Complete the development of countermeasure research protocols, and begin testing a minimum of three countermeasures intended to protect bone, muscle, and physical work capacity.**

Target achieved: Testing began for three countermeasures, including bisphosphonates, resistive exercise, and potassium citrate. Bed-rest simulation studies are in progress to evaluate the efficacy of bisphosphonates on the prevention of bone loss. Bed-rest simulation studies are also in progress to evaluate the efficacy of resistive exercise in preventing bone loss. A treadmill with vibration isolation and stabilization designed for the ISS was evaluated during Shuttle mission STS-81 (Figure 40). The treadmill flight article has been delivered to Kennedy Space in preparation for launch on flight 2A.2. The first trainer has been delivered, and the components for the other trainers and backup flight units have been obtained and will be assembled in FY 2000. A flight experiment was selected for STS-107 to test efficacy of potassium citrate for reducing risk to astronauts of kidney stone formation

Figure 40. Astronauts Test the Treadmill on Atlantis *During STS-81*

- **Perform component and subsystem ground tests without humans in the loop to demonstrate advanced technologies, including the biological water processor, and flight test a new electronic "nose" sensor on a chip.**

Target achieved: Numerous components and subsystems have been tested to date. Technologies tested in NASA ground-based facilities in FY 1999 include packed-bed and membrane biological water processors, air evaporation phase separation, reverse osmosis, vapor-phase catalytic ammonia removal, incineration, and supercritical water oxidation. The Immobilized Microgravity Microbial Water Production Processor is currently undergoing shakedown testing preparatory to flight. Flight test of NASA's electronic nose was conducted successfully on STS-95 in October 1998. The electronic nose combines an array of conducting polymers with neural net computer technology to detect a broad array of chemicals in the air while consuming only minimal power and volume.

Goal: Prepare to conduct human missions of exploration

Objective: In partnership with the Space Science Enterprise, carry out an integrated program of robotic exploration of the solar system to characterize the potential for human exploration and development

During FY 1999, the HEDS Enterprise pursued future human exploration beyond Earth orbit by partnering with the Space Science Enterprise in carrying out collaborative robotic exploration in support of future human exploration and development. This included participation on the planning team for the Space Science Enterprise's Mars Surveyor Program. HEDS selected two investigations for inclusion on the Mars Surveyor Program 2001 Lander mission and conducted a workshop to develop recommendations for research areas for a similar mission in 2003. In addition, HEDS pursued advanced technology planning and innovative mission studies to make more affordable human exploration missions possible in the future.

An additional key step has been the development of a new strategic plan for HEDS that embodies a number of innovative programmatic approaches to this critical challenge. A central theme is partnering with the Space Science Enterprise. HEDS is preparing for human exploration through robotic exploration missions conducted in collaboration with the Space Science Enterprise and others. A second theme is the definition of revolutionary concepts and the development of breakthrough technologies to make future exploration safer, more affordable, and more effective. HEDS is defining innovative human exploration approaches and planning for future investments in the development of high-leverage technologies to enable safe, effective, and affordable human/robotic exploration, including extending significantly scientific discovery on missions of exploration through the integrated use of human and machine capabilities.

HEDS is planning for the future conduct of engineering and human health research on the ISS to enable exploration beyond Earth orbit. Using ISS and ground-based research and development, HEDS is planning to develop capabilities common to both exploration and the commercial development of space through private-sector and international partnerships. Finally, HEDS is working to engage and involve the public in the excitement and the benefits of—and in setting the goals for—the exploration and development of space. The performance targets were to:

- **Initiate a collaborative program to design and develop radiation and soil/dust measuring devices.**

Target achieved: HEDS selected two Principal Investigators to develop and build scientific instruments to characterize the radiation environment and soil/dust environments through a joint Office of Space Science/OLMSA Announcement of Opportunity, utilizing the OLMSA peer review process. The development and integration of these instruments into the 2001 Lander have been coordinated with the Mars Surveyor Project Office at the Jet Propulsion Laboratory. A Critical Design Review for these experiments was conducted in April 1999.

- **Plan for the demonstration of *in situ* propellant production.**

Target achieved: The target was achieved through the planning and implementation of a Mars In-Situ Propellant (MIP) experiment that will be carried on the Mars Surveyor Program's Mars 2001 Lander. HEDS completed a Critical Design Review for the integrated system in May 1999. Qualification testing is under way.

Objective: Explore and invest in enabling cross-cutting technology and studies that can affordably open up the frontiers for human space exploration where there is a compelling rationale for human involvement

The performance target was to:

- **Evaluate options and define the exploration technology investment plan.**

Target achieved: This target was achieved through the definition of Design Reference Mission (DRM) options for several potential targets, including detailed studies for Mars (DRM 3.0) and initial studies of other options (for example, Libration Points, Moon, and Asteroids). In addition, technology roadmaps for exploration were refined and preliminary planning completed (and presented to the Office of Management and Budget) for a FY 2001 HEDS Technology/Commercialization Initiative to address exploration and commercial development of space technology needs.

Goal: Aggressively seek investment from the private sector, increase the affordability of space operations through privatization and commercialization, and share HEDS knowledge, technologies, and assets that promise to enhance the quality of life on Earth

Objective: Promote investments in commercial assets as pathfinders in ISS commercial operations and reduce the cost of Space Shuttle operations through privatization, eventual commercialization, and flying payloads

FY 1999 included substantial progress toward promoting commercial investment on the ISS. HEDS developed policy recommendations leading to a White House legislative initiative to establish an ISS Commercial Demonstration Program. Congress subsequently enacted the initiative in modified form. Pursuant to this initiative, HEDS is developing a Provisional Pricing Policy for ISS resources available through the Commercial Demonstration Program. A series of commercial offers received in FY 1999 are in various stages of negotiation. NASA expects to announce the first three commercial projects within the Space Station Commercial Development Program in FY 2000. The Space Shuttle program continued to make great strides to privatize operations under the United Space Alliance Space Flight Operations Contract. Because of this effort, in FY 1999, the Space Shuttle program continued to safely reduce personnel levels. The Space Shuttle civil service workforce decreased from 1973 to 1884. The performance target was to:

- **Complete the development of a commercialization plan for the ISS and Space Shuttle in partnership with the research and commercial investment communities, and define and recommend policy and legislative changes.**

Target partially achieved: The Commercial Development Plan for the ISS was completed and delivered to Congress during November 1998. A White House legislative initiative to establish the "International Space Station Commercial Demonstration Program" to establish a pricing policy for the ISS was submitted to Congress during July 1999. Several additional policy and legislative proposals in are final draft. The development of a Space Shuttle commercialization plan has been delayed. George Washington University is assisting NASA with the development of a detailed plan. The expected completion is now March 2000.

Objective: Reduce space communications and operations costs through privatization and eventual commercialization

NASA's space, deep space, and ground networks successfully supported all NASA flight missions and

numerous commercial, foreign, and other Government agency missions. Included were the first U.S. launch of ISS hardware (the Unity Node), NASA's third Great Observatory (the Chandra X-ray Observatory), the Mars Polar Lander, Stardust, Cassini Venus and Earth encounters, and Galilean moon encounters. The networks provided data delivery for all customers in excess of 98 percent. Other significant activities included the transition to a Consolidated Space Operations Contract (CSOC), the initiation of Deep Space Network (DSN) service upgrade to Ka-band capability, the completion of DSN 26-meter automation, the initiation of a Mars communications infrastructure phase A study, the completion of an upgrade to the Space Network Control Center, the negotiation of co-primary status for a unified S-band spectrum, and the initial acquisition of commercial ground network services.

The CSOC phase-in was completed between October and December 1998 with the transition of nine legacy contracts at Goddard Space Flight Center, Johnson Space Center, Marshall Space Flight Center, Kennedy Space Center, and the Jet Propulsion Laboratory on schedule with no significant problems. Cost performance is on track, customer operations are meeting proficiency targets, and workforce reductions are being effected consistent with the plan. This contract is expected to save taxpayers approximately $1.4 billion over 10 years. The performance targets were to:

- **Reduce space communications operations costs by 30 to 35 percent compared to the 1996 budget, through a consolidated space communications contract to meet established budget targets.**

Target achieved: Space communications costs have been reduced by 32 percent, compared to the FY 1996 budget.

- **Develop options and recommendations to commercialize space communications.**

Target not achieved: NASA developed initial options and recommendations to commercialize space communications. The final Space Operations and Management Commercialization Plan will be submitted to Congress during FY 2000. The plan will include fully developed options and recommendations to commercialize space communications.

Objective: Foster consortia of industry, academia, and government; leverage funding, resources, and expertise to identify and develop space commercial opportunities

The HEDS Space Product Development program works in partnership with industry through 14 Commercial Space Centers representing more than 100 affiliated companies and institutions. The program facilitates access to space for commercially sponsored research to bring the opportunities for new advances, technological understanding, products, and jobs. Some highlights of this work, as reported by the Commercial Space Centers, include:

- The production of the antibiotic actinomycin D—used in conjunction with cancer treatments—by microorganisms was 75 percent higher in microgravity than in comparable ground control experiments, providing Bristol-Myers Squibb, an industry partner of BioServe, with new insights that may improve ground-based production.
- Technology for creating high-temperature superconducting wires (which will reduce the size of transformers, increase efficiency, and make them more environmentally friendly by eliminating the need for oil cooling) using oxide thin films has been licensed by Metal Oxide Technologies from the Space Vacuum Epitaxy Center, which developed the technology in cooperation with the Texas Center for Superconductivity. A pilot plant for producing high-temperature superconducting wires for use in power line transformers is expected to be operational by 2001.
- A gene transfer experiment by Rapigen, LLC, and its partners showed that microgravity provided at least a tenfold increase in the successful transfer of traits to soybean seedlings over ground-based 0.1-percent success rates—an especially important point given that the U.S. Department of Agriculture estimates that more than 70 percent

of the soybeans planted in the Untied States are of genetically engineered varieties. This research was supported by the Astroculture™ project of the Wisconsin Center for Automation and Robotics.

The performance targets were to:

- **Increase non-NASA investment (cash and in-kind) in space research from $35 million in FY 1996 to at least $50 million in FY 1999, a 40-percent increase.**

Target achieved: Total non-NASA cash and in-kind investment, as reported by HEDS Commercial Space Centers, was $51.2 million for FY 1999.

- **Establish a new food technology Commercial Space Center.**

Target achieved: The Food Technology Commercial Space Center was competed and awarded to Iowa State University. Corporate partners include Kraft Foods, Maytag, and Pioneer. The center's metrics include commercial success, committed funds from commercial partners, educational grants, and research grants. The award is documented in the NASA Headquarters Press Release C99-b, available on line at *ftp://ftp.hq.nasa.gov/pub/pao/contract/1999/c99-b.txt*.

Objective: Involve our Nation's citizens in the adventure of exploring space and transfer knowledge and technologies to enhance the quality of life on Earth

During FY 1999, HEDS continued to sponsor a variety of programs and initiatives that support the Agency's Education Plan and that are in line with the National Education Goals to improve math and science literacy. Particularly noteworthy is the development of the first HEDS Education Implementation Plan by the HEDS Integrated Communication Team. Specific education projects, such as EarthKam and the Shuttle Amateur Radio Experiment (SAREX), directly involve students in Shuttle flights. Students (K–12) had the opportunity to participate with researchers in the analysis and interpretation of research data. HEDS also developed and operated an online project called Space Team Online. This project focuses on the people behind the scenes who make the Shuttle fly, and it uses the Internet to connect primarily K–12 students with NASA's Shuttle team.

HEDS initiated the Window on the Universe program. This initiative establishes a national network of 15 underserved communities committed to sustainable communitywide science, mathematics, and technology education. The program will use human space flight and the space sciences to engage entire communities, facilitating sustainable intracommunity linkages among school districts; museums, science centers, and planetariums; K–13 educators; local area researchers and amateur astronomers; business and civic organizations; and the public at large. The Stellar program, which seeks to use life sciences research to enhance teaching materials and curriculum, entered its fifth year, producing a 4-week summer workshop, a third CD–ROM for high school students, and internet Stellar lessons.

HEDS supported several targeted conferences and events in 1999, including the National Science Teachers Association, the National Biology Teachers Association, and the National Council of Teachers of Mathematics. Also, three collaborative efforts were initiated with museums in FY 1999. Star Station One Institute, a nonprofit organization of 61 U.S. science-technology centers, focused on ISS outreach and worked with OLMSA life sciences to develop a series of Garfield images illustrating facts about space physiology. These images were translated into web products, a poster, and black-and-white coloring book images for use in classrooms. In addition, the Life Sciences Museum Partners Network was established in 1999, to bring a small group of museums/science-technology centers together with NASA life sciences. A third museum partnership called "Science by Mail" was created with the Boston Museum of Science for which thousands of kits were distributed in FY 1999. The performance targets were to:

- **Initiate a curriculum development program, in partnership with the International Technology Education Association (ITEA), for gravity-related educational modules for national distribution that meet the current National Science Teachers Association (NSTA) National Standards for Science for Grades K–12 and the**

ITEA National Standards for Technology Education to be published June 1999.

Target achieved: Eight K–12 educational modules (two modules per grade grouping of K–2, 3–5, 6–8, and 9–12) titled "Microgravity: Earth and Space" have been developed by the NASA/ITEA curricula writing team and reviewed by NASA scientists and engineers, along with field testing by various technology teachers/schools around the country. The expected publication date for the modules was the fall of 1999. Although the ITEA has not published its National Standards for Technology Education, originally planned for release in March 1999, its technology "standards framework and standard areas" were utilized in the development of the modules in lieu of the specific technology education standards to meet the publishing timeframe. The reader can review the results through a review of *http://www.iteawww.org/iteawww/B2i.html* (documents ITEA and NASA Microgravity education grant) and of *Microgravity: Earth and Space—K–12 Activity Guide for Teaches and Students in Technology Education, Science, and Mathematics.*

- **Expand the microgravity research program World Wide Web–based digital image archive established in 1998 by 50 percent.**

Target achieved: The Microgravity Research Program Office digital image archive was established in January 1998 with 200 images. The archive is a fully text searchable web-based database, available to the general public. The image gallery contained 300 images and associated descriptions at the end of FY 1999. The Microgravity Research Program Office internal and external customers have access to the digital image archive through a public web site at *http://microgravity.nasa.gov/MGImages/UTILS/search.mg1.cgi*.

- **Conduct at least two demonstrations of the applicability of the "Telemedicine Instrumentation Pack" for health care delivery to remote areas.**

Target achieved: Two demonstrations of the Telemedicine Instrumentation Pack (TIP) were made in 1999—one in Montana and one in Corpus Christi, Texas. The performance was optimal in both cases. The TIP was developed as an initial package of medical equipment for remote environments where trained medical care and facilities would be very limited or nonexistent. In addition to application during space missions, the TIP is being developed for commercial application on Earth.

- **Demonstrate the application of laser light scattering technology for the early detection of eye-tissue damage from diabetes; publish results in peer-reviewed open literature.**

Target achieved: Two talks were given at the NASA-JDF-NIDDK Diabetic Retinopathy Workshop held in Washington, D.C., on March 30–31, 1999, and two papers were published in the *Journal of Diabetes Technology & Therapeutics* in 1999, which describe the use of this technique for diabetes diagnosis. Additional details on the workshop can be found at the Research Triangle Institute web site at *http://www.rti.org/technology/*.

As part of the Microgravity Research Program, recent advances in dynamic light scattering instrumentation developed under the fluid physics program at Glenn Research Center have made available extremely sensitive and compact fiber optic probes. These new-generation probes are found to detect a growing cataract at the molecular level—that is, several orders of magnitude earlier than the current clinical capabilities. These probes are also being applied to study the effects of diabetes on vitreous collagen cross-linking and aggregation of fibrils into larger than normal "bundles" of parallel collagen fibrils in the vitreous. We are also using these probes to study the light scattered from a diabetic cornea.

HEDS Data Validation and Verification

The HEDS Enterprise holds each of the program and project managers fully accountable for the accuracy of the performance information that is duly reported through the normal management and reporting processes. A review of the progress against each of the targets has been incorporated into management reviews at all levels within the HEDS organizations.

Seventy-five years of aerospace accomplishments are depicted in this montage illustration by artist Fred Otnes, commemorating the creation of the National Advisory Committee for Aeronautics (NACA) in 1915 and its successor agency, the National Aeronautics and Space Administration (NASA), in 1958.

Aero-Space Technology Enterprise

The Aero-Space Technology Enterprise pioneers the identification, development, verification, transfer, application, and commercialization of high-payoff aeronautics and space transportation technologies. The Enterprise plays a key role in maintaining a safe and efficient national aviation system and an affordable, reliable space transportation system. The Enterprise directly supports national policy in both aeronautics and space as directed in the "President's Goals for a National Partnership in Aeronautics and Research Technology," the National Space Policy, and the National Space Transportation Policy.

Strategic Goals and Objectives

The Enterprise has four strategic goals:

- Enable U.S. leadership in global aviation through safer, cleaner, quieter, and more affordable air travel
- Revolutionize air travel and the way in which aircraft are designed, built, and operated
- Enable the full commercial potential of space and expansion of space research and exploration
- Enable, as appropriate, on a national basis, world-class aerospace research and development services, including facilities and expertise, and proactively transfer cutting-edge technologies in support of industry and U.S. Government research and development

Each of the Enterprise goals has one or more specific objectives to further define and shape the technology needs and accompanying investments. The outcome-focused nature of the objectives project a preferred end-state within the air and space transportation systems. The achievement of these objectives requires a multiyear investment in research, technology development, and both ground and flight verification tests to reflect this multiyear path to achievement. Performance targets established annually to measure progress toward each objective inherently cover a wide spectrum of impact, ranging from early investigative research to final technology verification activities.

Performance Measures

In FY 1999, the Enterprise set 17 performance targets to measure progress toward 8 specific objectives. The Enterprise met or exceeded 12 of these targets, with the remaining 5 assessed as "not fully accomplished." With respect to the latter, two were completed by the end of the calendar year, with the remaining three projected to be met during FY 2000. The following material provides a detailed discussion of FY 1999 performance against each of the goals, objectives, and targets.

Goal: Enable U.S. leadership in global aviation through safer, cleaner, quieter, and more affordable air travel

The first Aero-Space Technology goal addresses the crucial challenges facing the air transportation system: safety, environmental concerns, and capacity. NASA, working in close cooperation with the Federal Aviation Administration (FAA) and industry, is strongly committed to the safety of the traveling public, the protection of the environment, and accessible, capable air transportation.

Although the specific targets established for FY 1999 focused on safety and air quality, progress also continued in the areas of community noise reduction, airport capacity improvements (including airport demonstrations with both Dallas-Ft. Worth and Minneapolis-St. Paul), and technology to reduce the weight and cost of future aircraft through the application of advanced composite materials. Highlights of performance for each target of the FY 1999 plan follow.

Objective: Contribute to aviation safety by reducing the aircraft accident rate

The performance targets were to:

- **Characterize the Super-cooled Large Droplets (SLD) icing environment, determine its effects on aircraft performance, and acquire and publish data to improve SLD forecasting confidence.**

Figure 41. Twin Otter Icing Research Aircraft

Target partially achieved: Under the Aviation Operations Systems Program, Glenn Research Center's Twin Otter Icing Research Aircraft completed flight tests for the 1998–99 winter icing season with high-fidelity icing cloud instrumentation mounted underside its wing (Figure 41). In combination with instrumentation comparison testing from the Glenn's Icing Research Tunnel conducted in November 1998, this database provides enhanced knowledge of ice formation processes. The program did not anticipate the wealth of data gathered; therefore, reduction and analysis were only 70 percent complete at the end of the fiscal year. The remainder was completed by the end of the calendar year. Both activities were a cooperative effort with Atmospheric Environmental Services (AES) of Canada and the FAA to improve understanding of severe icing hazard and thus enhance aviation safety.

- **Identify the contributing causes to be addressed, potential solutions using current capabilities, and gaps that require technology solutions for the aviation safety areas of controlled flight into terrain, runway incursion, and loss of control.**

Target achieved: Over 30 percent of all fatal accidents worldwide are categorized as controlled flight into terrain (CFIT) accidents, in which a functioning aircraft collides with terrain or obstacles that the flight crew were unable to see (Figure 42). As part of the Airframe Systems Program, several underlying causes of CFIT were identified, and 13 2- to 3-year contracts were awarded to develop and demonstrate approaches for fully operational and certifiable synthetic vision (7 awards) and health management (6 awards) systems. The preparation for flight evaluation of a crew-centered synthetic vision display was also completed, as was a study of synthetic vision applicability to general aviation aircraft.

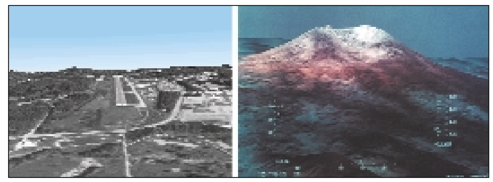


Figure 42. Controlled Flight Into Terrain (CFIT)

Objective: Contribute to environmental compatibility by reducing aircraft emissions

The performance target was to:

- **Demonstrate an advanced turbine-engine combustor that will achieve up to a 50-percent reduction of oxides of nitrogen emissions based on the 1996 International Civil Aviation Organization (ICAO) standard.**

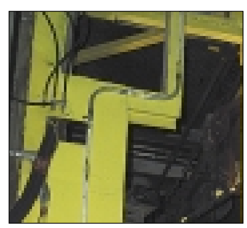


Figure 43. Low-Emission Combustor

Target achieved: As part of the Advanced Subsonic Technology Program, a low-emission combustor was demonstrated on a Pratt & Whitney 4000 development engine (Figure 43). The low-emission combustion concept utilizes initially rich front-end combustion followed by air-quench and lean combustion. The engine was operated over the normal operating envelope with both conventional and low-sulfur fuel, and it included limited combustor operability and durability assessments. The results included reductions in oxides of nitrogen (NOx) levels during landing and takeoff cycle (below the 50-percent 1996 ICAO regulation), reductions in carbon monoxide and unburned hydrocarbon levels (below regulation), and comparable reductions in cruise NOx emissions (40 percent).

Goal: Revolutionize air travel and the way in which aircraft are designed, built, and operated

The second Enterprise goal represents an investment in technology that could revolutionize air transportation as we know it today. Significant potential exists to greatly reduce "doorstep-to-destination" travel time from higher speed commercial transports for overseas travel, as well as direct "point-to-point" personal aircraft for shorter domestic trips. New design tools to reduce engineering cycle time and costs, as well as experimental aircraft for exploring new concepts and complementing laboratory research, are also integral elements of this investment. The Enterprise had many exciting accomplishments in support of this goal during FY 1999, as described below.

Objective: Advance high-speed travel by enabling the development of the High Speed Civil Transport

The performance target was to:

- **Produce a complete vehicle system configuration document that includes the impact of technology validation efforts from 1990 through 1999. This document will support the evaluation of technology selection decisions for a future High Speed Civil Transport.**

Figure 44. High Speed Research

Target achieved: A new complete vehicle system was developed that reflected the impacts of the High Speed Research program technology validation efforts and updated technology projections (Figure 44). The technology configuration met or exceeded all of the original program goals, most notably the takeoff noise goal, which was met despite a significant increase in stringency over the duration of the program. The vehicle maximum takeoff gross weight met the program-defined limit for economic viability, and it also met the travel time objective of the high-speed travel goal. The program goal of a 20-percent ticket surcharge was nearly met, although still above the zero surcharge element of the high-speed travel goal.

Objective: Revitalize general aviation

The performance target was to:

- **Conclude preflight ground testing of the general aviation piston and turbofan engines.**

Target not achieved: Although slowed by technical problems, progress continued during FY 1999 in NASA's cooperative efforts with industry to develop advanced engine technology for general aviation aircraft. Both the advanced internal combustion engine and the small gas turbine engine completed assembly and initial performance and operability testing (Figure 45). Design modifications to correct problems uncovered during the ground-based tests were completed and incorporated in their respective rebuilds. Testing is scheduled to resume in early 2000. Confidence remains high that at least one of the engines can be demonstrated on experimental aircraft at the Summer 2000 Oshkosh Fly-In in Wisconsin.

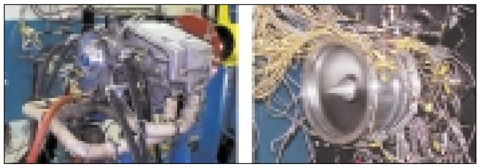


Figure 45. General Aviation Engines

Objective: Develop next-generation experimental aircraft

The performance targets were to:

- **Complete low-altitude flights of an RPA (Remotely Piloted Aircraft) with a wingspan greater than 200 feet, suitable for flight to 100,000 feet in altitude once outfitted with high-performance solar cells.**

Target achieved: The Flight Research Program completed the first low-altitude flight of a Helios

prototype in September 1999. The flight demonstration included a battery-powered RPA with a wingspan greater than 245 feet, suitable for flight to 100,000 feet in altitude or a duration of 100 hours once outfitted with high-performance solar cells (Figure 46). Based on the excellent results from these flights, the procurement of advanced solar cells will be initiated during 2000.

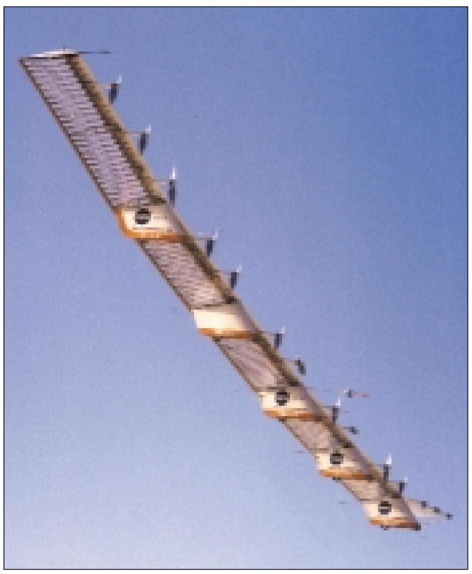


Figure 46. Helios RPA

- **Conduct Remotely Piloted Aircraft (RPA) flight demonstrations to validate the capability for science missions of greater than 4 hours duration in remote deployments to areas such as the polar regions above 55,000 feet.**

Target achieved: In July 1999, the Flight Research Program conducted an RPA flight demonstration of the General Atomics Altus vehicle at Edwards Air Force Base (Figure 47). The purpose of the demonstration was to validate RPA technology for use in science missions with a duration of greater than 4 hours, deployed to areas such as the polar regions above 55,000 feet. The flight demonstration was a success and further increases design confidence in the application of RPA's as science measurement platforms.

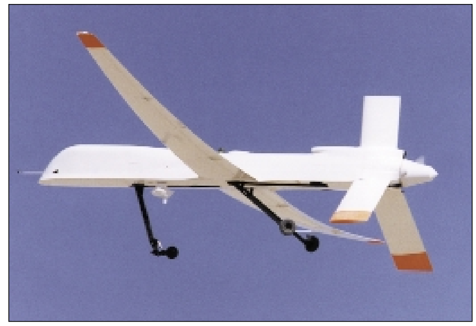


Figure 47. Altus RPA

Objective: Develop next-generation design tools

The performance targets were to:

- **Demonstrate up to a 200-fold improvement over the 1992 baseline (reduce from 3,200 hours to 15) in the time to solution for a full combustor simulation on NASA's National Propulsion System Simulation advanced applications on computational testbeds that can be increased to sustained teraFLOPS capability.**

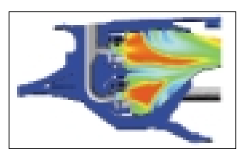


Figure 48. Computer Simulation

Target achieved: In September 1998, the High Performance Computing and Communications Program achieved a 200:1 reduction in turnaround time (3,174 hours on the Intel Paragon computer or 13 hours on the Silicon Graphics Origin 2000 computer) on a full combustor simulation from compressor exit to turbine inlet. In June 1999, the reduction turnaround time improved to 307:1 and, by year end, was at 320:1—10 hours on the Silicon Graphics Origin 2000 (Figure 48). This improvement in the National Combustor Code will contribute to a significant reduction in aircraft engine combustor design time and cost by reducing the need for combustor rig testing by one-third, resulting in a savings estimated at $2 million. This will also aid in accomplishing the national goal to reduce aircraft engine emissions.

- **Demonstrate communication testbeds with up to 500-fold improvement over the 1996 baseline (increase from 300 kilobits per second to 150 megabits per second) in end-to-end performance.**

Target achieved: With the use of IP Multicast technology, satellite communications, and Internet 2 partnerships, the testbeds demonstrated an advanced high-fidelity three-dimensional imaging and interactive virtual environment to simultaneously review medical images remotely in real time with an aggregate bandwidth of 175 megabits per second to reach geographically diverse end sites.

Goal: Enable the full commercial potential of space and expansion of space research and exploration

The X-33 and X-34 advanced technology demonstrators are a part of NASA's ongoing efforts to pave the way for commercial development of reusable launch vehicles that will dramatically reduce cost and increase the reliability of space transportation. Progress toward initial flight tests of both vehicles continued during FY 1999, but both efforts were affected by events as described below.

Objective: Revolutionize space launch capabilities

The performance targets were to:

- **Continue the X-33 vehicle assembly in preparation for flight testing**

Target achieved: Testing of the first development of the Aerospike Engine for the X-33 began during FY 1999 at Stennis Space Center. The second and third engines, the flight engines for the X-33, were scheduled for acceptance tests at Stennis near the end of the calendar year (Figure 49). Unfortunately, the liquid hydrogen tank for the vehicle experienced a delamination (separation of the tank's skin from its honeycomb structure) following pressure and structural load testing at Marshall Space Flight Center in early November 1999. An evaluation of the latter and an assessment of its impact to the program were initiated in December and will continue into early 2000.

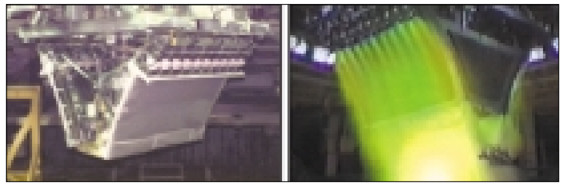


Figure 49. X-33 Testing

- **Complete vehicle assembly, and begin flight testing of the X-34.**

Target not achieved: Although slowed by hardware delivery problems and the resolution of environmental concerns at the White Sands Test Facility, progress toward the first flight of the X-34 continued during FY 1999 (Figure 50). Hot-fire testing of the Fastrac engine was initiated at Stennis, and the assembly of the first powered flight vehicle (A-2) continued. The replanned program includes the modification of vehicle A-1 (used for captive-carry testing with the L-1011 launch aircraft), as an unpowered test asset for testing at White Sands, with powered testing (using vehicle A-2) moved to Dryden Flight Research Center at Edwards Air Force Base. Program replanning also includes a change in engine test sites from Stennis to Rocketdyne's facility in California. The first unpowered flight of the assembled X-34 is now scheduled for April 2000.

Figure 50. Two Views of the X-34

Goal: Enable, as appropriate, on a national basis, world-class aerospace research and development services, including facilities and expertise, and proactively transfer cutting-edge technologies in support of industry and U.S. Government research and development

A unique aspect of the Aero-Space Technology Enterprise is that it is entirely dependent on external organizations to implement its technology products and services. This supplier-customer relationship makes it critical that the Enterprise solicit feedback from the user community to fully gauge its performance. The following objectives and FY 1999 performance targets embody this emphasis on the customer, including the Enterprise's education outreach efforts.

Objective: Provide world-class aerospace research and development services, facilities, and expertise

The performance targets were to:

- **Complete 90 percent of Enterprise-controlled milestones within 3 months of schedule.**

Target not achieved: Each Enterprise program uses measurable, customer-negotiated product and service deliverables to track annual performance against plans, including specific success criteria. This metric aggregates performance of all individual program milestones to provide a composite indicator of progress toward the 10 objectives of the Enterprise's 3 technology goals. The Enterprise completed 84 percent of its planned FY 1999 deliverables within the 3-month metric; 6 percent were completed 4 to 6 months late (Figure 51).

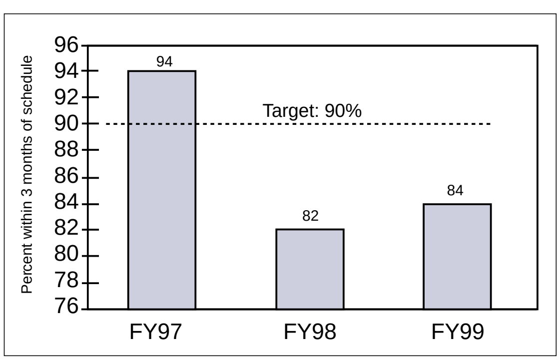


Figure 51. Enterprise Milestones Completed

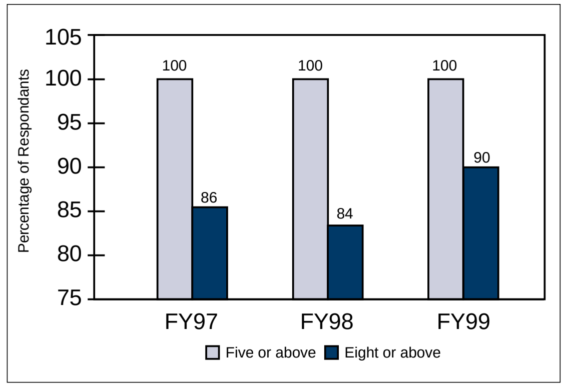


Figure 52. Facility Utilization Satisfaction

- **Achieve a facility utilization customer satisfaction rating of 95 percent of respondents at "5" or better and 80 percent at "8" or better based on exit interviews.**

Target achieved: One of the major services provided to its customers by the Enterprise is access to NASA's critical research and development facilities, such as wind tunnels. Each of the four NASA Research Centers (Ames, Dryden, Langley, and Glenn) conducts exit interviews at selected facilities. This metric aggregates the interview results to provide an overall indicator of customer satisfaction relative to the Enterprise research and development services goal. Facility-by-facility data are available and used to improve customer satisfaction. The Enterprise metric is to have 80 percent of facility exit interview respondents rate satisfaction with aeronautics facilities (on a scale of 1 to 10) at "8" or above and 95 percent rate facilities at "5" or above. For FY 1999, the Enterprise exceeded both goals, scoring 90 percent and 100 percent, respectively (Figure 52).

- **Complete the Triennial Customer Satisfaction Survey, and achieve an improvement from 30 percent to 35 percent in "highly satisfied" ratings from Enterprise customers.**

Target achieved: The Enterprise serves a range of customers, including the aviation and related industries, the academic community, nonaviation industries, and other Government agencies (such as the Department of Defense and the FAA). This measure

provides direct feedback from users and partners on the level of satisfaction with NASA technology activities supporting the 10 objectives of the Enterprise's 3 technology goals, but also with respect to the research and development services goal. The metric is to consistently improve the percentage of respondents that rate the Enterprise at "8" or above (on a scale of 1 to 10), with 90 percent rating the Enterprise at "5" or above. Based on the latest survey, the Enterprise improved on the "8" and above rating (from 30 to 35 percent), with the "5" and above rating approaching 90 percent (Figure 53).

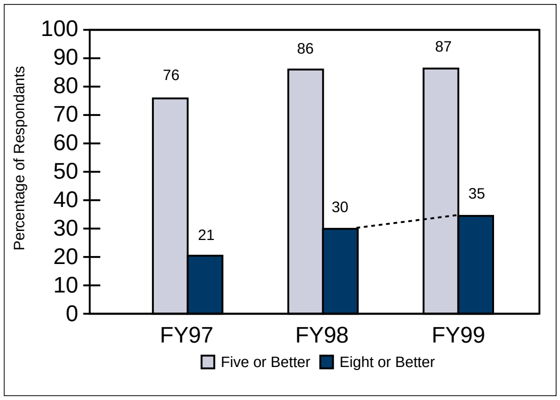


Figure 53. Triennial Survey of Customer Satisfaction

- **Transfer at least 10 new technologies and processes to industry during the fiscal year.**

Target achieved: Twelve new technologies and processes were transferred to industry and other Government agencies during FY 1999:

- Super-cooled liquid droplet ice formation process
- Crack detection technologies leading to two commercial nondestructive evaluation instruments for aircraft inspection
- Combustion technology with 50-percent reduction in NOx
- Stitching fabrication process for advanced composites with 20-percent cost reduction
- Four new high-temperature materials developed during the High Speed Research Program—one airframe and three propulsion
- RPA technology for 4-hour duration over 55,000 feet altitude
- Computational technology with 200-fold reduction in time to solution
- Communication technology with 500-fold improvement in end-to-end performance

- **Establish an Aeronautics Education Laboratory in at least three new sites in the United States.**

Target achieved: Eight new sites were established in FY 1999: Wayne County Community College (Detroit, Michigan); Sinclair Community College (Dayton, Ohio); Cuyahoga Community College (Cleveland, Ohio); Virginia Air & Space Center (Hampton, Virginia); York College (Jamaica, New York); Fenger Academy (Chicago, Illinois); Harris-Stowe State College (St. Louis, Missouri); and Warren County High School (Warrenton, North Carolina).

- **For all new program activities initiated in FY 1999, develop an education outreach plan, which includes and results in an educational product. This product shall be consistent with current educational standards and use program content to demonstrate or enhance the learning objectives.**

Target not achieved: The plan will be completed in FY 2000, although one educational product was created during FY 1999.

Aero-Space Technology Enterprise Data Validation and Verification

With the exception of the survey and education outreach targets, the data used to substantiate actual performance originated at the NASA Field Centers responsible for program implementation. The data were verified by senior officials at those Field Centers and also during the periodic Enterprise review process at NASA Headquarters, including the NASA Program Management Council on selected programs and projects. The above assessment was also reviewed by the Aero-Space Technology Committee of the NASA Advisory Council.

"Emergence," acrylic on canvas by Dan Namingha. The artist combined his Indian heritage, the Hopitewa spirituality and mysticism, with today's technology.

Manage Strategically

This Crosscutting Process ensures that the Agency carries out its responsibilities effectively and safely and that management allocates resources to support NASA's strategic goals and objectives. NASA made substantial progress in FY 1999 toward aligning the Agency's management decisions and resource allocations with national policies and statutes, Agency plans, and budget guidelines. This progress is reflected in (a) the improved alignment of our human, physical, and financial resources with customer requirements; (b) the improved effectiveness and efficiency in our acquisitions processes by using techniques and management to enhance contractor innovation and performance; and (c) improvements in our information technology capability and services.

Goal: Provide a basis for the Agency to carry out its responsibilities effectively and safely, and enable management to make critical decisions regarding implementation activities and resource allocations that are consistent with the goals, objectives, and strategies contained in NASA's Strategic, Implementation, and Performance Plans

Objective: Optimize investment strategies and systems to align human, physical, and financial resources with customer requirements, while ensuring compliance with applicable statutes and regulations

Of the six targets established for this objective, NASA met four targets, exceeded one target, and failed to meet the sixth target. The performance targets were to:

- **Reduce the civil service workforce to below 19,000.**

Target achieved: Actual Full-Time Equivalent (FTE) usage for FY 1999 was 18,469 (Figure 54). The FY 1999 target was met through attrition.

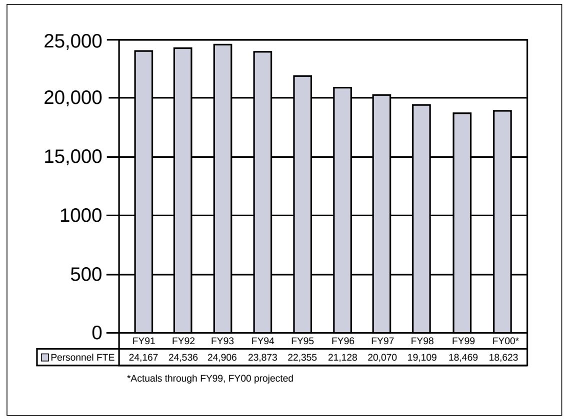


Figure 54. Personnel FTE

- **Maintain a diverse NASA workforce through downsizing efforts.**

Target achieved: In FY 1999, NASA maintained a diverse workforce. Since 1992, the percentages of minorities, women, and individuals with targeted disabilities have increased, while the total workforce size decreased from 24,536 to 18,469 (Figure 55).

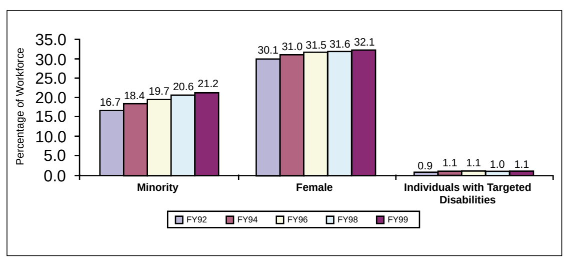


Figure 55. Workforce Diversity

- **Reduce the number of Agency lost workdays (from occupational injury or illness) by 5 percent from the FY 1994–96 3-year average.**

Target achieved: NASA's FY 1994–96 injury rate was 0.36 lost time injuries per 200,000 work hours. A 5-percent-per-year reduction from this rate yields an FY 1999 goal of 0.31 lost time injuries per 200,000 work hours. NASA's actual FY 1999 rate was 0.19 lost time injuries per 200,000 work hours (Figure 56).

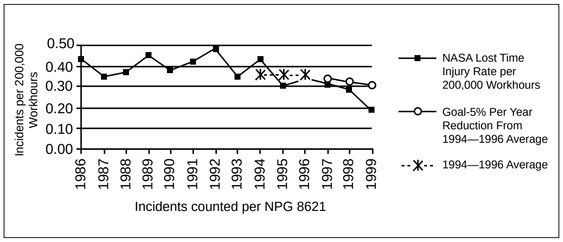


Figure 56. Lost Time Injury Rates

■ **Achieve a 5-percent increase in physical resource costs avoided through alternative investment strategies in environmental and facilities operations.**

Target achieved: The Office of Management Systems achieved a cost avoidance of $128.09 million (Figure 57). The FY 1999 target was exceeded by 163 percent, as a result of cost avoidance realized through the use of alternative investment strategies. Indicators of improved facilities engineering, environmental management, and logistics management are validated by analyses of data (and comparisons against benchmarks) obtained from Field Center reports, the NASA Environmental Tracking System database (which contains information on activities at Field Centers related to pollution prevention, energy conservation, and recycling activities), and Annual Personal Property Reports.

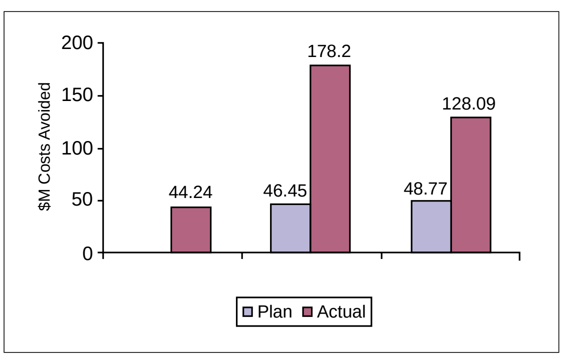


Figure 57. Cost Avoidance

■ **Achieve 70 percent or more of the resources authority available to cost within the fiscal year.**

Target achieved: NASA successfully met the target to cost at least 70 percent of the resources available to cost, achieving a cost record of 82 percent against our annual plan (Figure 58). This target provides NASA with a measure of the effective utilization of the financial resources made available to us and indicates that NASA is not allowing a disproportional percentage of the resources to lie unutilized.

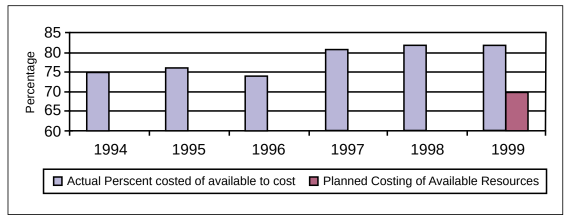


Figure 58. Available Resources Costed

■ **Complete system validation of the Integrated Financial Management Program, and complete system implementation at Marshall and Dryden**

Target not achieved: Validation testing of the delivered system from KPMG revealed substantially more defects that anticipated. This resulted in instituting a more comprehensive program of software testing and remediation than planned. In addition, key resources needed for the Marshall and Dryden implementations were tied up with software remediation. These two events combined have resulted in a 12-month slip in schedule. NASA is now reassessing the contractor's ability to carry out implementation.

Objective: Improve effectiveness and efficiency of Agency acquisitions through the increased use of techniques and management that enhance contractor innovations and performance

NASA has met the three targets. The performance targets were to:

■ **Increase Performance Based Contract (PBC) obligations to 80 percent of funds available for PBC (funds available exclude grants, cooperative agreements, actions less than**

$100,000, the Small Business Innovation Research and Small Business Technology Transfer programs, Federally Funded Research and Development Centers, intragovernmental agreements, and contracts with foreign governments or international organizations).

Target achieved: NASA obligated 81 percent of the funds that were available for PBC's (Figure 59). Indicators of progress in meeting the targets are verified through the Financial and Contractual Status (FACS) system, which contains data from acquisitions activities at all Centers. NASA Headquarters also periodically examines a sampling of contracts to determine whether they meet the definition of a "performance based contract."

Procurement surveys conducted after the data were reported have identified issues with the FACS system data that potentially could result in a variance of 2 percent against the data reported for FY 1999

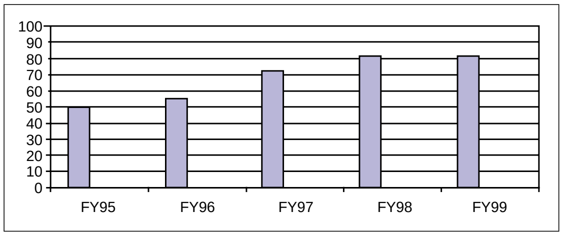


Figure 59. PBC Obligations

- **Achieve at least the congressionally mandated 8-percent goal for annual funding to small disadvantaged businesses (including prime and subcontracts to small disadvantaged businesses, Historically Black Colleges and Universities, other minority educational institutions, and women-owned small businesses).**

Target achieved: NASA funding for small disadvantaged businesses was 16.1 percent in FY 1999, the highest level achieved to date (Figure 60). Data are reported from both the NASA Centers (using SF 278 and SF 281) and the prime contractors (using SF 295).

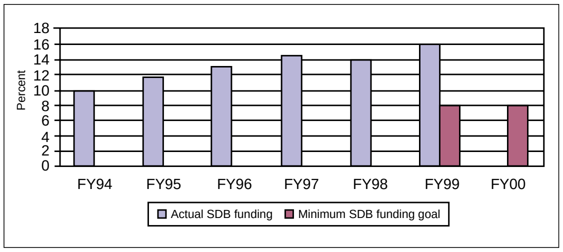


Figure 60. Percentage of Funds to Small Disadvantaged Businesses

- **Enhance contract management through improved systems and information for monitoring and through an emphasis on the training of procurement personnel, and revise metrics to assess the overall health of the procurement function**

Target achieved: The target has been met by the Office of Procurement through the implementation of a revised set of procurement metrics to assess the health of the function. A final metrics report was issued in November 1998, and the Office of Procurement regularly collects resultant data and prepares reports.

- **Enhance contract management through improved systems and information for monitoring by implementing a strategy for evaluating the efficacy of procurement operations.**

Target achieved: The revised strategy has been implemented through a combination of Headquarters-led procurement surveys, periodic Center self-assessments, and periodic ISO audits. A revised self-assessment guide was issued in November 1998, and each Center has submitted an initial sample self-assessment to Headquarters for review. Headquarters procurement management survey teams review Centers triennially and validate their contract management activities. The Centers reviewed in FY 1999 were Goddard Space Flight Center, the NASA Management Office at the Jet Propulsion Laboratory, Kennedy Space Center, and Ames Research Center.

Objective: Improve information technology capabilities and services

NASA has made significant progress toward improving information technology capability and services, as is indicated by our achievement of the two targets. The performance targets were to:

- **Improve information technology infrastructure service delivery to provide increased capability and efficiency while maintaining a customer rating of "satisfactory" and holding costs per resource unit to the FY 1998 baseline.**

Target achieved: NASA met its target performance for both customer satisfaction and operational efficiency in FY 1999. Performance for both factors is determined through the measurement of Agencywide services provided through both the NASA ADP Consolidation Center (NACC) and the NASA Integrated Service Network (NISN). For NACC, the customer satisfaction baseline was substantially exceeded, and the cost of NACC support dropped dramatically because of technology enhancements (Figure 61). For NISN, customer satisfaction remained at or above baseline levels, while the cost of NISN support rose slightly because of the addition of a significant number of additional international circuits (Figure 62).

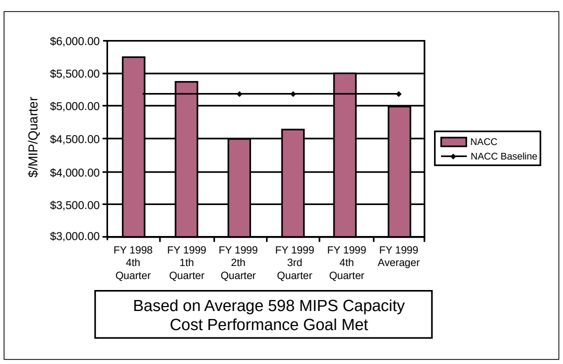


Figure 61. NACC Unit Cost Metric

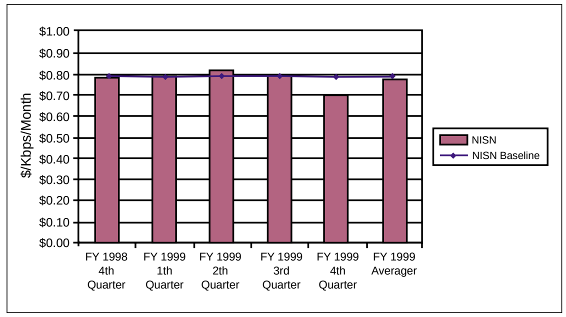


Figure 62. NISN Unit Cost Metric

- **Complete the remediation of mission-critical systems by March 1999, consistent with Governmentwide guidance for the Year 2000.**

Target achieved: NASA completed 100 percent of the mission-critical remediation by March 1999 (Figure 63).

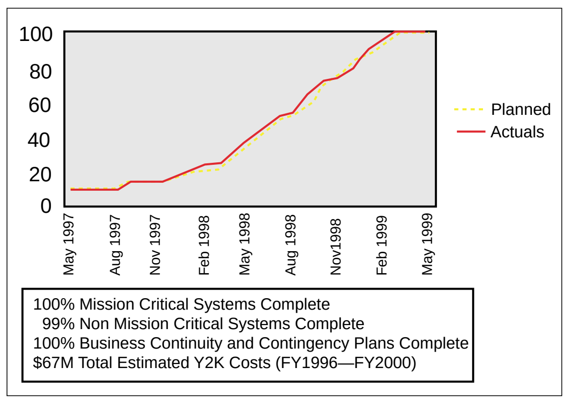


Figure 63. NASA Is Year 2000 Ready

Provide Aerospace Products and Capabilities

This Crosscutting Process is the means by which NASA's Strategic Enterprises and their Centers deliver systems (ground, aeronautics, and space), technologies, data, and operational services to NASA customers. Through the use of Agency facilities, customers can conduct research, explore and develop space, and improve life on Earth. This process is conducted by and enables NASA's four Strategic Enterprises and their Centers to deliver products and services to customers more effectively and efficiently. In FY 1999, NASA demonstrated successful performance for each of the four objectives of the Provide Aerospace Products and Capabilities process, as supported by the targets.

Goal: Enable NASA's Strategic Enterprises and their Centers to deliver products and services to customers more effectively and efficiently while extending the technology, research, and science benefits broadly to the public and commercial sectors

Objective: Reduce the cost and development time to deliver products and operational services

NASA's role in the advancement of research and technology is conducted through the construction and operation of facilities such as telescopes, satellites, and ground-based laboratories and test facilities. In FY 1999, NASA's performance for this objective was successful. The performance targets were:

- **Meet schedule and cost commitments by keeping the development and upgrade of major scientific facilities and capital assets within 110 percent of cost and schedule estimates, on average.**

Target achieved: Costs for the development and upgrade of major scientific facilities and capital assets were an average of 110 percent of cost estimates. Schedules for the development and upgrade of major scientific facilities and capital assets were an average of 110 percent of schedule estimates (Figure 64).

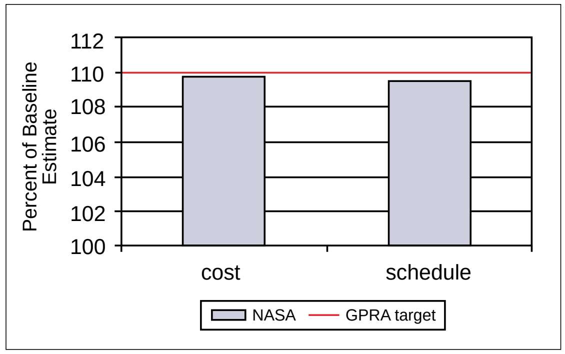


Figure 64. NASA Cost and Schedule Performance

- **Reduce the 5-year average spacecraft cost for Space Science and Earth Science Enterprise missions to $200 million from $590 million.**

Target not achieved: The 5-year average spacecraft cost for Space Science and Earth Science Enterprise missions was reduced from $590 million to $210 million (Figure 65). Although the specific target was not achieved, the reduction in average spacecraft cost was significant. The reduction of the 5-year average spacecraft cost for Space Science and Earth Science Enterprise missions from $590 million to $210 million demonstrates the significant progress made by NASA in this area. This progress represents a decrease to less than half the previous average spacecraft cost.

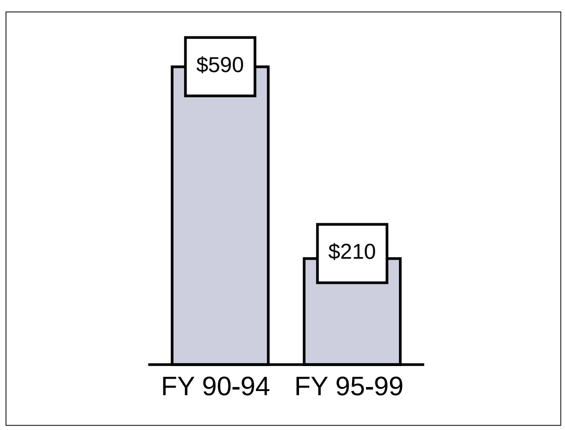


Figure 65. Five-Year Average Earth and Space Science Spacecraft Cost

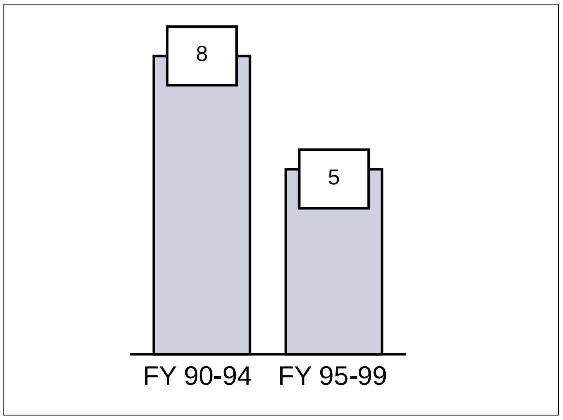


Figure 66. Five-Year Average Earth and Space Science Spacecraft Development Time

- **Reduce the 5-year average spacecraft development time for Space Science and Earth Science Enterprise missions to 5 years, 2 months from 8 years, 3 months.**

Target achieved: For FY 1999, the 5-year average spacecraft development time for Space Science and Earth Science Enterprise missions was reduced from 8 years, 3 months to 5 years, 0 months (Figure 66). The performance target for spacecraft development time was achieved. The reduction of the 5-year average spacecraft development time for Space Science and Earth Science Enterprise missions from 8 years, 3 months to 5 years clearly demonstrates the significant progress made by NASA in this measurement area. This represents a twofold decrease in the average spacecraft development time.

Objective: Improve and maintain NASA's engineering capability

NASA's performance in this area was successful. The performance targets for space and ground facilities that deliver engineering data and engineering tools and skills were both met. The performance targets were to:

- **Set up process to determine, on average, the operating time of NASA's spacecraft and ground facilities lost to unscheduled downtime, and establish a baseline in FY 1999.**

Target achieved: All Enterprise processes to determine the average operating time lost to unscheduled downtime were developed. Using data provided for FY 1999, the baseline was established. It was found that on average, 5.6 percent of scheduled operating time was lost to unscheduled downtime. The Agency goal is to have less than 10 percent of operating time lost to the unscheduled downtime, on average.

- **Set up a process to improve engineering skills and tools within the Agency.**

Target partially achieved: NASA has established the Collaborative Engineering Environment and future engineering tools and skills development as part of Intelligent Synthesis Environment (ISE) program. Objectives and metrics were defined, and both a draft Program Commitment Agreement and Program Plan were completed. Internal program approval for the ISE was delayed because of nonadvocate review recommendations and additional communication required with NASA stakeholders. It is anticipated that the extant issues with the ISE program will be resolved in FY 2000 and that the FY 2000 performance target will be accomplished, as planned. The systems engineering core capabilities assessment is in process, and a skill mix adjustment may be required to meet future missions.

Objective: Capture and preserve engineering and technological process knowledge to continuously improve NASA's program/project management

The performance target was to:

- **Set up process in FY 1999 to capture a set of best practices/lessons learned from each program, including at least one from each of the four Provide Aerospace Products and Capabilities subprocesses, commensurate with current program status.**

Target achieved: The process to provide and manage the Provide Aerospace Products and Capabilities process knowledge has been developed. The Agency's Lessons Learned Information System was modified to manage the Provide Aerospace Products and

Capabilities process knowledge lessons learned and best practices. Enterprises are to provide inputs beginning in FY 2000.

Objective: Focus on integrated technology planning and development in cooperation with commercial industry and other NASA partners and customers

The performance targets were to:

- **Set up a data collection process to determine the amount of leveraging of the research and development budget with activities of other organizations, and establish a baseline in FY 1999.**

Target achieved: The process for collecting these data has been established and used to capture the extent of the technology (research and development) budget leveraging in FY 1999. Currently available FY 1999 data provide a preliminary baseline: NASA invested a total of $59.5 million in 55 formal joint activities with other Government agencies.

This metric is intended to measure NASA's investment in technology research and development with activities of other organizations. For purposes of establishing the baseline, data corresponding to activities formally documented with other Government agencies were collected. The data for this metric are collected as part of the Technology Inventory that is administered by the Chief Technologist. Subsequent to the completion of FY 1999, this function has been transferred to the Office of Aero-Space Technology. The database is updated on an annual basis. The inputs are validated by at least one level of management at the Centers and subsequently by Enterprise representatives at NASA Headquarters.

- **Set up a process to determine the percentage of the Agency's research and development budget dedicated to commercial partnerships, and establish a baseline.**

Target achieved: This process was completed during FY 1999. Using data input by the NASA Centers during FY 1999, the baseline was defined. The Agency contributed 13.9 percent of its research and development investment to commercial partnerships. The Agency goal is to have 10 to 20 percent of the dollar value of the total research and development program involved in commercial partnerships.

The Office of Aero-Space Technology's Commercial Technology Division administers this metric's collection and reporting via NASA TechTracS, the Agencywide commercial technology management information system. An Agencywide team called the NASA Commercial Technology Management Team, which consists of the heads of each Center's Commercial Technology Office and a representative from each Enterprise, supports the Commercial Technology Division. Langley Research Center leads a NASA TechTracS subteam. Each Commercial Technology Office ensures that appropriate and valid partnership data are entered into NASA TechTracS in a timely fashion.

Generate Knowledge

NASA provides new scientific and technological knowledge gained from exploring the Earth system, the solar system, and the universe beyond, and from conducting the necessary supporting research and development. The Generate Knowledge Crosscutting Process ensures that this information is shared with scientists, engineers, and technologists in industry, academia, and other organizations. In addition, natural resource managers, policymakers, and educators benefit from this process. The goals of the Generate Knowledge process are to extend the boundaries of knowledge of science, technology, and engineering, to capture new knowledge in useful and transferable media, and to share new knowledge with customers.

The Generate Knowledge process is conducted by NASA's four scientific research enterprises: the Space Science Enterprise, the Earth Science Enterprise, and the Office of Life and Microgravity Sciences and Applications within the Human Exploration and Development of Space Enterprise (OLMSA/HEDS), and the Aero-Space Technology Enterprise. The process does not include research of a proprietary industrial nature or research whose conduct or dissemination is limited for reasons of national security.

The process goal is supported by two primary objectives. Three performance targets were established for the FY 99 Performance Plan.

Goal: Extend the boundaries of knowledge of science, technology, and engineering, capture new knowledge in useful and transferable media, and share new knowledge with customers

Objective: Select research projects through peer-reviewed and merit-based competition

The performance target was to:

- **Submit 80 percent of Agency research projects to peer-reviewed processes. Proposals submitted to NASA for funding will be selected through a merit-based competitive process. (Codes S, U, and Y)**

Target achieved: NASA selected 82 percent of its research through peer-reviewed processes.

Enterprise	$ of Research	Percentage Conforming	$ Conforming
Space Science R&A	$176 million	98%	$173 million
Space Science DA	$211 million	96%	$203 million
Space Science Tech.*	$198 million	33%	$ 66 million
Earth Science	$155 million	90%	$140 million
OLMSA	$218 million	97%	$211 million
Total	$958 million	82%	$793 million

*These figures represent only technology research applicable to multiple objectives. Technology development activities that support only a single program or project are not included.

Note: Other peer-reviewed research, part of Provide Aerospace Products and Capabilities, among others, is not incorporated above.

Objective: Provide information to the public and data to researchers

The performance objectives were to:

- **Provide monthly updates for all missions and, where possible, on a weekly basis. (Codes R, S, U, and Y)**

Target not achieved: NASA projects supplied monthly mission communications for 97 percent of the projects identified for this performance target.

Enterprise	No. of Projects	No. Conforming
Space Science R&A	26	25
Earth Science	11	11
OLMSA	1	1
Aero-Space Technology	0	0
Total	38	37

- **Make available for researchers fully calibrated, verified, and validated science data products within 1 year of acquisition. (Codes R, S, U, and Y)**

Target not achieved: NASA released 93 percent of the targeted science data products within 1 year.

Enterprise	No. of Projects	No. Conforming
Space Science	20	18
Earth Science	6	6
OLMSA	3	3
Aero-Space Technology	1	1
Total	30	28

Communicate Knowledge

During the past 4 decades, the results of NASA's scientific activities and discoveries have proven to be extremely important to the American people and to the world. NASA has a unique charter in the Space Act of 1958 to "provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof." NASA uses the Communicate Knowledge process to increase understanding of science and technology, advance its broad application, and inspire achievement and innovation. The process augments the transfer of technology that is performed within the normal course of conducting research, performing missions, and executing overall the Agency's programs and projects. Communicate Knowledge is a process that ensures that the knowledge derived from the public's investment is presented and transmitted to meet the specific needs and interests of the public, educators, and NASA's constituency groups.

The goal of this process is to ensure that NASA's customers receive the information derived from the Agency's research and technology development efforts that they want, when they want it, for as long as they want it. Based on our performance in the areas of providing education, transferring technology, assisting customers in locating and using technical information, and providing a historical context for NASA's activities and achievements, we believe that the Agency has had a significant impact on communicating NASA-generated knowledge. All of the performance metrics were achieved or exceeded. Children, industry, and the public in general now have easier access to more relevant information than they have ever had in the past.

The goal was achieved through the efforts of many people and organizations, and NASA's progress toward the goal was measured by a series of performance targets that are categorized by two objectives:

1. Highlight existing and identify new opportunities for NASA's customers, including the public, the academic community, and the Nation's students, to directly participate in space research and discovery
2. Improve the external constituent communities' knowledge, understanding, and use of the results and opportunities associated with NASA's programs

Goal: Ensure that NASA's customers receive the information derived from NASA's research efforts that they want, in the format they want, for as long as they want it

Objective: Highlight existing and identify new opportunities for NASA's customers, including the public, the academic community, and the Nation's students, to directly participate in space research and discovery

To make people more aware and informed about NASA's activities, the Agency has been making a concentrated effort to reach out to students of all ages and to publicize specific technical achievements. In cooperation with educational associations for mathematics, science technology, and geography and science centers, more and more educators are being introduced each year to the latest science and engineering at NASA. The teachers are from all grade levels are expected to take back their newly acquired knowledge from NASA to their classrooms. Each of the Agency's 10 Centers conducts educational programs.

In addition to educational programs, the NASA Centers use the Internet to make the latest technological developments available to the public. For example, the recently enhanced *NASA Tech Briefs* web site is available to download Technical Support Packages, which provide in-depth information on the innovations described in the *NASA Tech Briefs* publications. NASA also uses the online edition of *Aerospace Technology Innovation*—the public's source for current information on NASA projects and opportunities in the areas of technology transfer and commercialization, aerospace technology development, and the commercial development of space.

Spinoff is yet another publication produced annually, featuring the successful commercial and industrial applications of NASA technology. Users can browse the 1996, 1997, 1998, and 1999 editions or go to

the *Spinoff* Home Page to submit their desired application of NASA technology, as well as search the database for leads. Another avenue for the public to "shop" for technology is by searching the NASA TechTracS system to find technology that is available for transfer, licensing, and commercialization. The Agency's search service scans across all of the NASA Commercial Technology sites to discover advanced technologies and commercialization opportunities. The performance targets were to:

- **Increase the number of educators who participate annually in NEWEST/NEWMAST (the programs have been combined and are being called NEW—NASA's Education Workshops) to 500 from 400 in FY 1998.**

Target achieved: There were 500 educators participating in NASA's Education Workshops (NEW) in FY 1999 (Figure 67). In grades K–12, 250 educators were chosen on a national competition basis, and 250 educators were selected on a State and regional basis in workshops managed by each of the NASA Centers.

- **Increase the number of students reached through the NEWEST/NEWMAST (NEW) program to 42,000 students from 33,600 in FY 1998.**

Target achieved: The program reached 42,250 students and achieved this metric for FY 1999 through a contracted arrangement with a national teachers association (Figure 68). The number of students reached is determined in the following way:

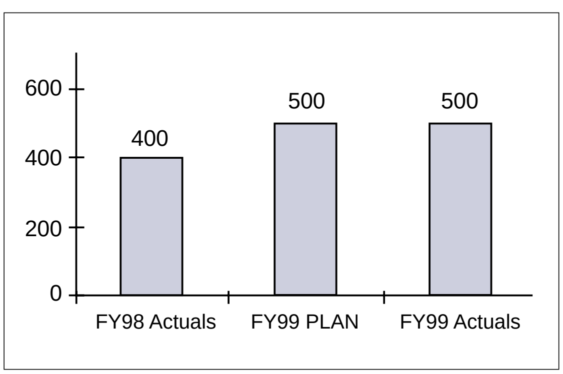


Figure 67. Number of Educators in NEW

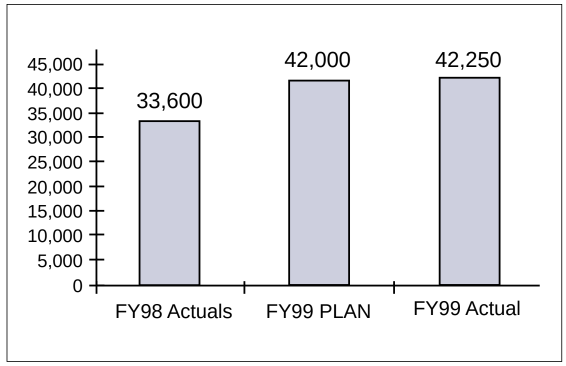


Figure 68. Number of Students Reached Through NEW

262 educators in grades K–6 interfacing with 25 students per educator and 238 educators in grades 7–12 interfacing with 150 students each (262 x 25 + 238 x 150 = 42,250). These numbers are provided by the National Science Teachers Association and are still valid estimates.

- **Maintain the participation level in Agencywide educational programs at more than 1 million teachers and students.**

Target achieved: There were 3,702,645 individuals who participated in the NASA educational programs, based on actual head counts.

- **Increase new technology opportunities from 19,600 to 19,700. These will be made available to the public through the TechTracS database and will be measured by monitoring a controlled data field that indicates the number of new technologies communicated to the public.**

Target achieved: In FY 1999, 409 new technologies were actually released to the public via the TechTracS system, clearly exceeding this target. However, because of the age of some of the technology listings in the system, 1,918 items were removed. The items that were removed continue to be available to the public via NASA's Scientific and Technical Information (STI) archive that is maintained by NASA's Center for Aerospace Information

(CASI). In May 1999, the TechTracS system recorded 19,869 items, exceeding the metric. At the end of FY 1999, the system only contained 18,091 items.

Objective: Improve the external constituent communities' knowledge, understanding, and use of the results and opportunities associated with NASA's programs

In our efforts to enhance the external communities' knowledge of NASA's programs and all the results of investments in the Agency, we have focused on a historic perspective and on enhancing our STI database.

In FY 1999, we reached our goal in historical publications that provide the public with a comprehensive understanding of the Agency's socioeconomic, technical, and scientific contribution from aeronautics and space. The public and the technical community have access to the Agency's documents, taped oral history interviews, biographical files, and much more. NASA also achieved its goal of sponsoring a special symposium—one of an ongoing program of events on current topics of historic significance.

This STI program acquires, processes, archives, and disseminates information for the scientific community. The information records basic and applied research results from the efforts of scientists and engineers. The material is available on paper, film, multimedia, and electronic format. This program produces technical and conference reports, technical translations, and special publications. In addition, periodic bibliographies, which range from technical, medical, and aeronautical subjects to NASA space flight video and NASA patents, are developed.

NASA's STI program reached, and in some cases exceeded, its performance targets in FY 1999. During this reporting period, record numbers of documents and bibliographic/citation records were added to the database, which is available online via the Internet. The performance targets were to:

- **Produce 10 new historical publications chronicling and placing NASA's activities and achievements in perspective for the American public, and sponsor or cosponsor one major scholarly conference.**

Target achieved: The following 11 publications and a CD–ROM were produced in FY 1999:

1. Braslow, Albert L. *A History of Suction-Type Laminar-Flow Control with Emphasis on Flight Research* (Monographs in Aerospace History, No. 13, June 1999)
2. Bromberg, Joan Lisa. *NASA and the Space Industry* (Baltimore: Johns Hopkins University Press, April 1999)
3. Heppenheimer, T.A. *The Space Shuttle Decision: NASA's Quest for a Reusable Space Vehicle* (NASA SP-4221, May 1999)
4. Hunley, J.D. Editor. *Toward Mach 2: The Douglas D-558 Program* (NASA SP-4222, June 1999)
5. Launius, Roger D. Editor. *Innovation and the Development of Flight* (College Station, TX: Texas A&M University Press, April 1999)
6. Logsdon, John M., General Editor, with Roger D. Launius, David H. Onkst, and Stephen J. Garber. *Exploring the Unknown: Selected Documents in the History of the U.S. Civil Space Program, Volume III: Using Space* (NASA SP-4407, November 1998)
7. Logsdon, John M. Moderator. *Managing the Moon Program: Lessons Learned from Project Apollo* (Monographs in Aerospace History, No. 14, July 1999)
8. Perminov, V.G. *The Difficult Road to Mars: A Brief History of Mars Exploration in the Soviet Union* (Monographs in Aerospace History, No. 15, July 1999)
9. Rumerman, Judy A. Compiler. *NASA Historical Data Book, Volume V: NASA Launch Systems, Space Transportation, Human Spaceflight, and Space Science 1979–1988* (NASA SP-4012, June 1999)
10. Tucker, Tom. *Touchdown: The Development of Propulsion Controlled Aircraft at NASA Dryden* (Monographs in Aerospace History, No. 16, September 1999)
11. Wallace, Lane E. *Dreams, Hopes, Realities: NASA's Goddard Space Flight Center, The First Forty Years* (NASA SP-4312, March 1999)

12. Garber, Stephen E. Compiler. *Remembering Apollo 11: The 30th Anniversary Data Archive CD–ROM* (June 1999).

Concerning the requirement for sponsoring or cosponsoring one major scholarly conference, the Agency achieved this requirement by hosting "Space Exploration at the Millennium: In Remembrance of Carl Sagan," a symposium cosponsored by NASA on March 24, 1999, at American University in Washington, D.C. The symposium featured presentations by Buzz Aldrin, Yvonne Cagle, Andrew Chaikin, Franklin Chang-Díaz, Hugh Downs, Ann Druyan, Timothy Ferris, Don Herbert, Homer Hickam, Ted Koppel, Bill Nye, Robert Pickardo, Ned Potter, Kim Stanley Robinson, Donna Shirley, Kathy Sullivan, and Jill Tarter, among others. This symposium offered a retrospective on one of this century's crowning accomplishments: the genesis of space exploration. It included panel discussions, numerous exhibits and displays, and small session meetings with several panelists. It proved to be exceptionally popular. Total attendance was more than 1,800 people, including school groups and many students from American University. The symposium was broadcast live on NASA TV and simulcast on MS/NBC, CBS Interactive, broadcast.com, and several other web-based media outlets. Reports from all of the major daily newspapers and news magazines were quite positive. Local television coverage was also impressive. Since the symposium, numerous people have asked the NASA History Division where they may obtain tapes of the symposium or a transcript of proceedings. Accordingly, 6-hour-long videotape of the symposium is now available from CASI.

- **Acquire 10,550 NASA-sponsored, -funded, and/or -generated report documents for the American scientific community and public, publish 26 issues of an electronic current awareness product to announce additions to the NASA STI database, and add 24,400 bibliographic/citation records to the online NASA STI database describing scientific and technical publications available to the American public.**

Target achieved: There were 30,938 citations acquired and input into STI database, as confirmed by performance monitoring of the contract for database inputs. The target was exceeded with the help of a focused thrust to leverage help from NASA organizations beyond the STI program. Twenty-six issues of electronic current awareness products were published and distributed. All issues were produced either ahead of schedule or on time. Also, 128,727 bibliographic/citation records added. This metric was exceeded because of a new focus on and approach to locating and adding commercially available sources and data buys in addition to exchange agreements.

In addition to the accomplishments described above, the Agency has also exceeded this target through the use of the national media. One example of Strategic Enterprise use of the media can be found in NASA's considerable efforts to increase the public's awareness of our Earth Science Enterprise activities. In 1999, the Earth Science Enterprise increased the number of annual national news releases threefold, providing at least one major national news story a month, contributing supporting video footage and animation that brought home the relevance of Earth Science Enterprise research to the American people. Examples of such news stories were the continuing studies of annual weather phenomena such as El Niño and La Niña, the monitoring of the global ozone situation, the use of satellite technologies for precision farming, and contributions to monitoring hurricane activities.

NASA Advisory Council (NAC)
Assessment of
FY 1999 Performance Plan

NASA Advisory Council

National Aeronautics and Space Administration
Washington, DC 20546

FEB 1 2000

Mr. Daniel S. Goldin
Administrator
National Aeronautics and Space Administration
Washington, DC 20546

Dear Mr. Goldin,

The NASA Advisory Council spent most of its December, 1999, meeting in the review of NASA's performance against its FY 1999 Performance Plan. As you know, the agency requested the Council to independently review its annual Performance Plan as a part of NASA's submission to Congress for the Government Performance and Results Act (GPRA).

The Council found the agency successfully achieved nearly all of its performance metrics for FY 1999. NASA should be proud of this accomplishment. While the agency did underperform in a few isolated areas, many of these problems were associated with launch delays beyond the agency's control.

The Council looks forward to having greater input into the development of the FY 2000 and FY 2001 plans in an effort to improve the process as we move forward. Additionally, if the FY 2000 plan does not cover areas where the Council expressed a need for performance targets, we request that modifications be made to the plan.

Sincerely,

Bradford W. Parkinson

Bradford W. Parkinson
Chair, NASA Advisory Council

NASA Advisory Council (NAC) Assessment of FY 1999 Performance Plan

The NAC was asked to evaluate the FY99 performance *against the approved plan* published in February 1999. Our evaluation *did not include events after October 1, 1999,* (for example, the recent Mars Polar Lander failure). The more recent successes and failures were not considered in this assessment and will be reflected in next year's report.

The Council offers the following general comments:

- NASA's self evaluation was very objective. In some of the cases, we increased the scores because of the significance of technical achievements that substantially exceeded the goals. In another case, a score was lowered to unsatisfactory.
- While this plan and process are commendable and are an excellent first step, the process clearly needs further improvement. For example, all goals do not have the same degree of difficulty and some weighting of significance and magnitude of the effort is desirable.
- The Council was <u>not</u> generally involved in setting the goals. For future evaluations, such involvement is important to achieve a total balance.

We believe that certain significant NASA efforts are not included in the Performance Measurement. <u>Examples</u> include:

1. Developing and executing a comprehensive launch vehicle strategy (a <u>critical</u> NASA need)
2. Developing a Crew Return Vehicle (CRV) for the International Space Station (ISS) (an important immediate safety concern and need for ISS)
3. Advances in Air Traffic Control technologies (help for the national air traffic control problems)
4. Shuttle Launch Rate and Safety (critical for assembly of the ISS and ongoing essential human-flight research)
5. New Rocket engine technology (the lynch pin for <u>any</u> future launch vehicle strategy)

We endorse the general concepts of better, faster, cheaper while recognizing there have been some problems in execution. Smaller and more numerous missions have been a desirable objective because of the severe constraints on the NASA budget. Better, faster, cheaper should not be taken as a justification to abandon processes that have proven essential to mission success. Constraining all three parameters (cost, schedule, and performance) can easily lead to greater risk. This risk should be clearly assessed, reported, and managed. It is important that all stakeholders understand this possible consequence. If the risk is not acceptable, relief from some of the constrained parameters will be required.

The following comments are specific to each of the evaluation areas:

Aero-Space Technology

The Office of Aero-Space Technology (OAT) programs are generally well focused and demonstrating good progress. Safety and environmental work are enhanced by a planned synergy of complementary work with Federal Aviation Administration (FAA). The attention to revitalization of flight research is well received. Infrastructure efforts to integrate and enhance design, development, technology tools (i.e. high speed computing) are outstanding. Additionally, some elements of OAT's "outreach" to their customers and academia are also excellent.

The Advisory Council notes the performance targets selected for review do not present a complete picture of current NASA efforts in the Aero-space Technology Enterprise. There is a two year time lapse between the definition and evaluation of the performance targets. For example, excellent progress has been made in the Air Traffic Area, but increased air traffic capacity goals are not noted as targets for the FY 1999 time period. Neither are targets noted for development of an integrated space transportation architecture; an activity now underway. The Council also notes while assembly of the X-33 vehicle was ontrack near the end of the fiscal year, enormous challenges remain.

The Council also advises that a clearer resolution should be established for any difficulties in achieving a given target; i.e. performance or schedule, reporting, outbriefs, and wrap-up. It is noted that the anti-icing program has provided an outstanding amount of data. While the technical performance is excellent, the data reduction/reporting workload became greater than planned (due to the success of the program). A grade of "yellow" for delayed reporting belies the excellent performance for the program.

Life and Microgravity Sciences and Applications

The Office of Life and Microgravity Sciences and Applications (OLMSA) met or exceeded all of the performance goals this year. The most significant accomplishments were:

- The research program has been strengthened by increasing the number of investigations.
- The Center for Evolutionary Biology was established and the first proposals were selected and funded.
- There were multiple scientific publications from research on MIR, Neurolab, and the Material Science Laboratory.

- Commercial Investment was increased and a new Commercial Space Center for food technology was established.
- Spin-off technology improved telemedicine health care delivery and diabetic eye care.

Given the current level of resources, the lack of human flight opportunities will prevent the attainment of the goals of understanding microgravity, preparing for long-term flight, and fostering commercialization. Future performance metrics should measure flight opportunities.

Space Science

The Space Science Enterprise did a good job of meeting its performance targets in FY 1999. There were seven successful launches. A fleet of earth-orbital and deep-space spacecraft continued to return new data. These data led to new scientific discoveries in topics ranging from planetary science to the earliest evolution of the Universe. One noteworthy success was verification that gamma-ray bursts originate from distant galaxies, making them the most powerful known radiation sources in the Universe. Another was the mapping of Mars by the Mars Global Surveyor spacecraft, which has exceeded expectations and is leading to a new and different understanding of that planets' history.

There were a few significant failures in FY 1999. The Wide-Field Infrared Explorer (WIRE) and Mars Climate Orbiter (MCO) spacecraft were both lost before they began their scientific missions. The Near Earth Asteroid Rendezvous (NEAR) failed to orbit the asteroid Eros, but will re-encounter Eros in FY 2000, and should still be able meet its objectives. Some setbacks are not to be unexpected in an aggressive program of space exploration. In its overall performance, the Space Science Enterprise clearly met a tough set of expectations in FY 1999.

Earth Science

The Office of Earth Science achieved their FY 1999 Performance Plan objectives. Key performance targets met during this period include:

- The first refresh of the global archive of 30 meter land imagery data since the 1970's from the Landsat-7 spacecraft launched in April 1999.
- The initiation of sea-surface speed and direction measurements at a resolution of 25km over 90 percent of the ice-free oceans every two days from the QuikSCAT spacecraft launched in June 1999.
- The previous concerns of the NAC regarding EOSDIS are alleviated by the excellent performance results displayed as part of the FY99 GPRA review.

- The application of Earth science data to practical societal needs through the development of over 100 new partnerships with industry, academia and other government agencies.

Of the targets not met, most were due to factors beyond NASA's control, notably re-certification of the commercially-procured launch vehicle for the TERRA spacecraft, and issues related to Russian participation in the SAGE III mission.

Space Shuttle and International Space Station

The FY99 goals established for the Office of Space Flight (OSF) have been successfully achieved. One of the more significant accomplishments has been the initiation of space station operations. Space shuttle goals need to be strengthened to include a 100 percent mission success goal and number of flights goal. Caution needs to be exercised in establishing goals that could encourage taking additional risk. Space Station goals need to include all critical events.

OSF has developed a Commercial Development Plan for International Space Station (ISS), but it is still lacking a similar plan in the Shuttle program. In areas of conducting human missions of exploration, the objectives are large and complex long-term programmatic efforts. While OSF accomplished their performance targets in these areas, the targets were only small steps in larger agency efforts.

Agency Cross-Cutting Processes

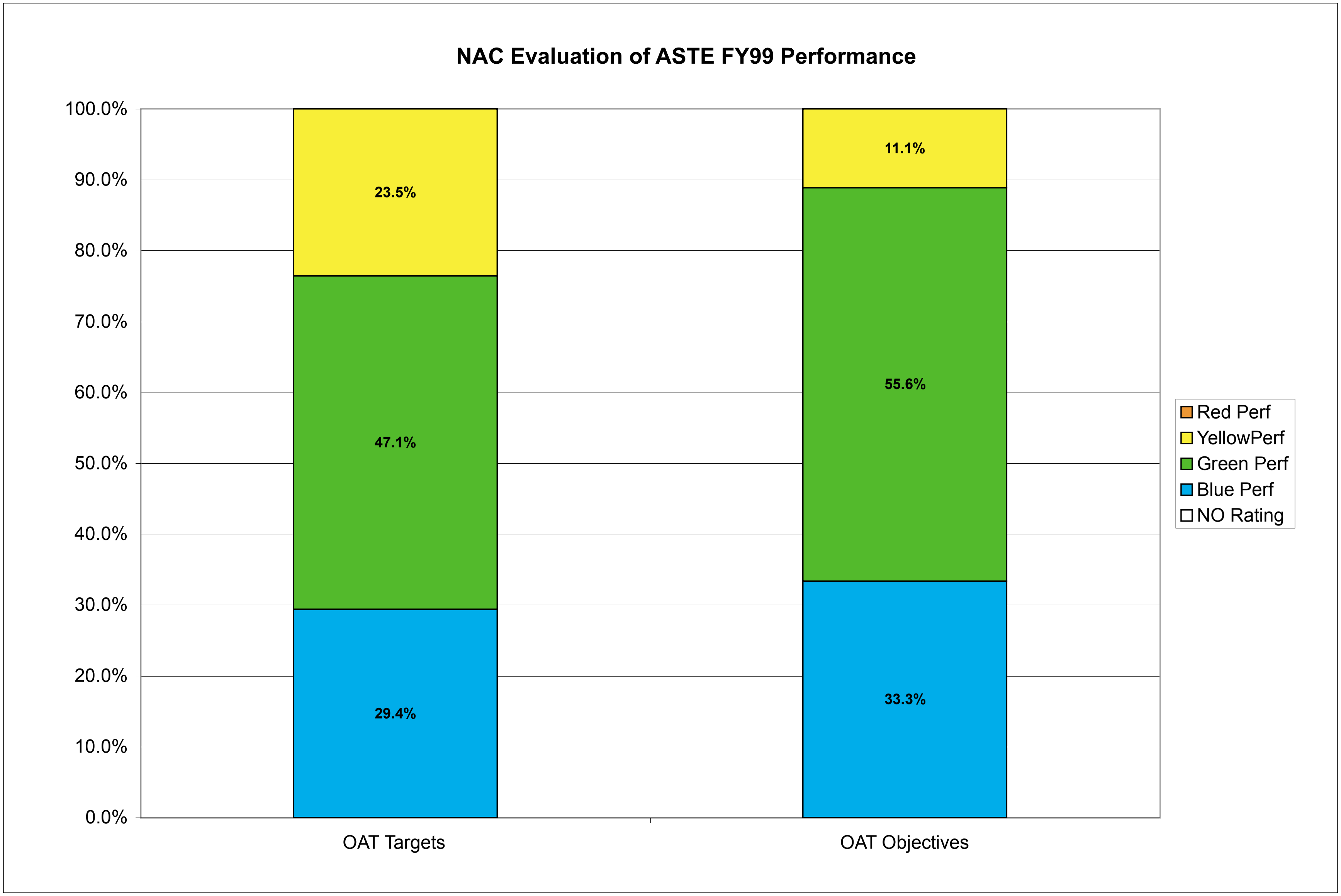
The agency achieved its FY 1999 Performance Plan objectives in its Cross-Cutting Processes. Of note, the agency should be commended in its efforts at Generating Knowledge and Communicating Knowledge. In particular, the agency was highly successful at selecting research projects by institutionalizing peer-reviewed and merit-based processes, and also at increasing the number of teacher (over 3 million) participants in NASA's educational programs.

NASA also made significant progress in delivering products and services to its customers more effectively and efficiently. In the area of managing strategically (ensuring that NASA carries out its responsibilities effectively and safely), the agency met several workforce-oriented performance targets including effectively managing the shrinking of its workforce in a government-wide initiative to reduce the size of the federal government. Additionally, NASA did a good job at managing its infrastructure resources by employing an effective cost avoidance strategy that emphasized environmental management, logistics management, and preventive maintenance at field centers.

An area of major concern is the lack of progress in implementation and validation of the agency's new Integrated Financial Management Program (IFMP). The Council downgraded the agency self-assessment in this area. The agency has failed to achieve the schedule goal for FY 1999. Additionally, serious technical problems continue to plague the overall IFMP effort. This area needs additional management attention throughout FY 2000, if the IFMP is to be successfully implemented.

Assessment Color Key

Blue – Significantly exceeded performance target
Green – Achieved performance target
Yellow – Did not achieve performance target, progress was significant and achievement is anticipated within next fiscal year
Red – Failed to achieve performance target, do not anticipate completion with next fiscal year, target may be infeasible or non-achievable.


NAC Evaluation of ASTE FY99 Performance
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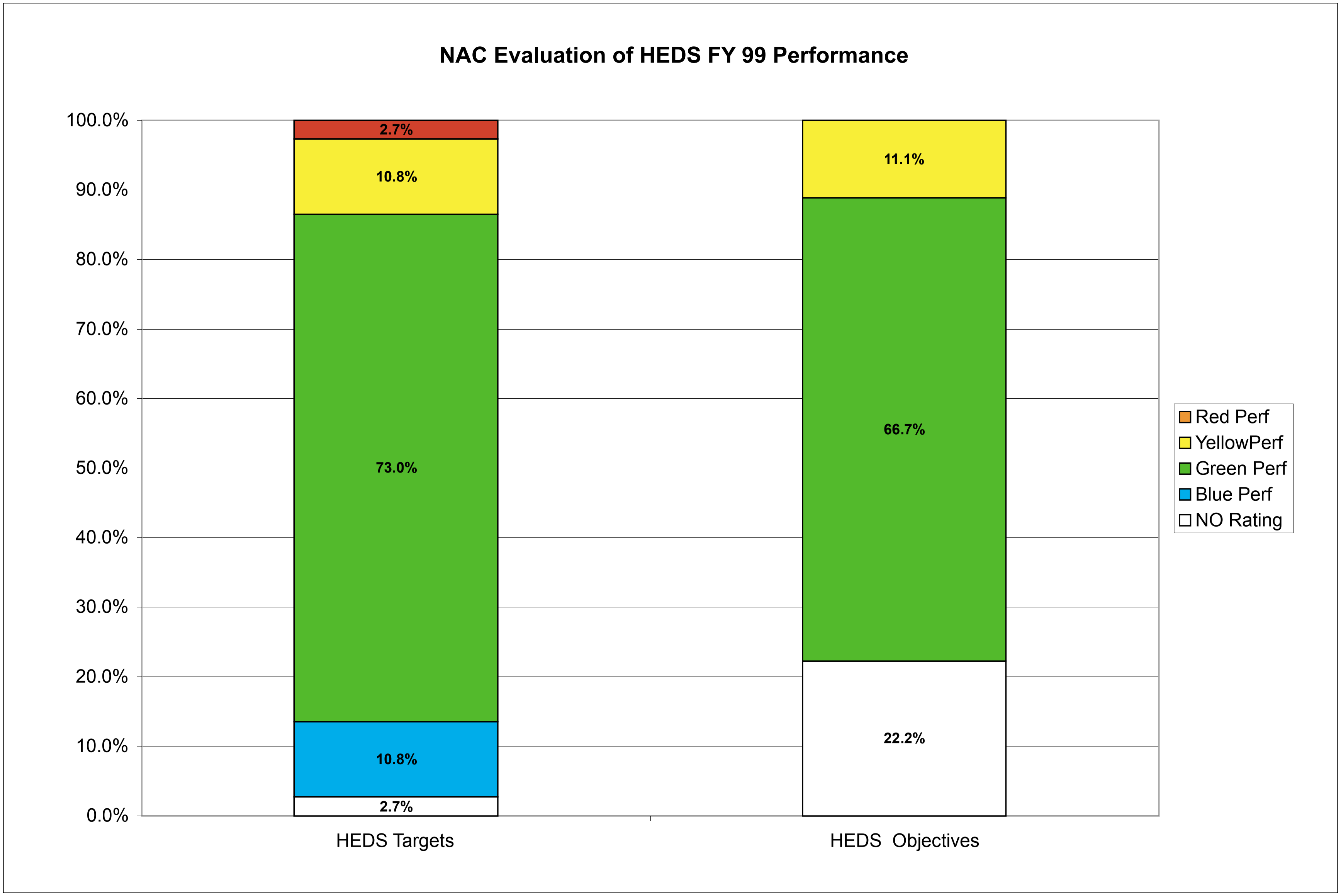
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
23.5%
47.1%
29.4%
11.1%
55.6%
33.3%
OAT Targets
OAT Objectives
Red Perf
YellowPerf
Green Perf
Blue Perf
NO Rating



NAC Evaluation of HEDS FY 99 Performance
100.0%
90.0%
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70.0%
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40.0%
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10.0%
0.0%
2.7%
10.8%
73.0%
10.8%
2.7%
11.1%
66.7%
22.2%
HEDS Targets
HEDS Objectives
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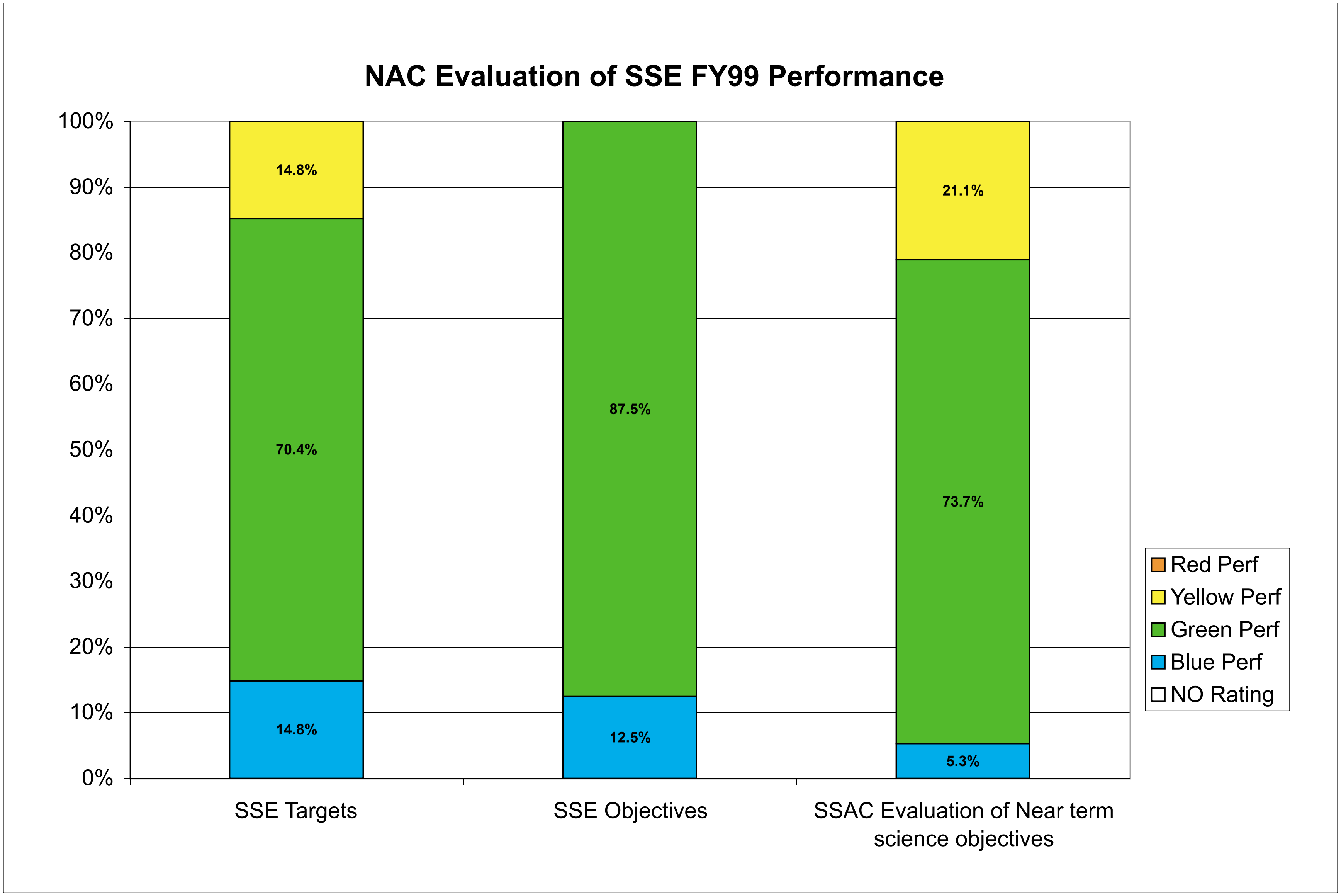
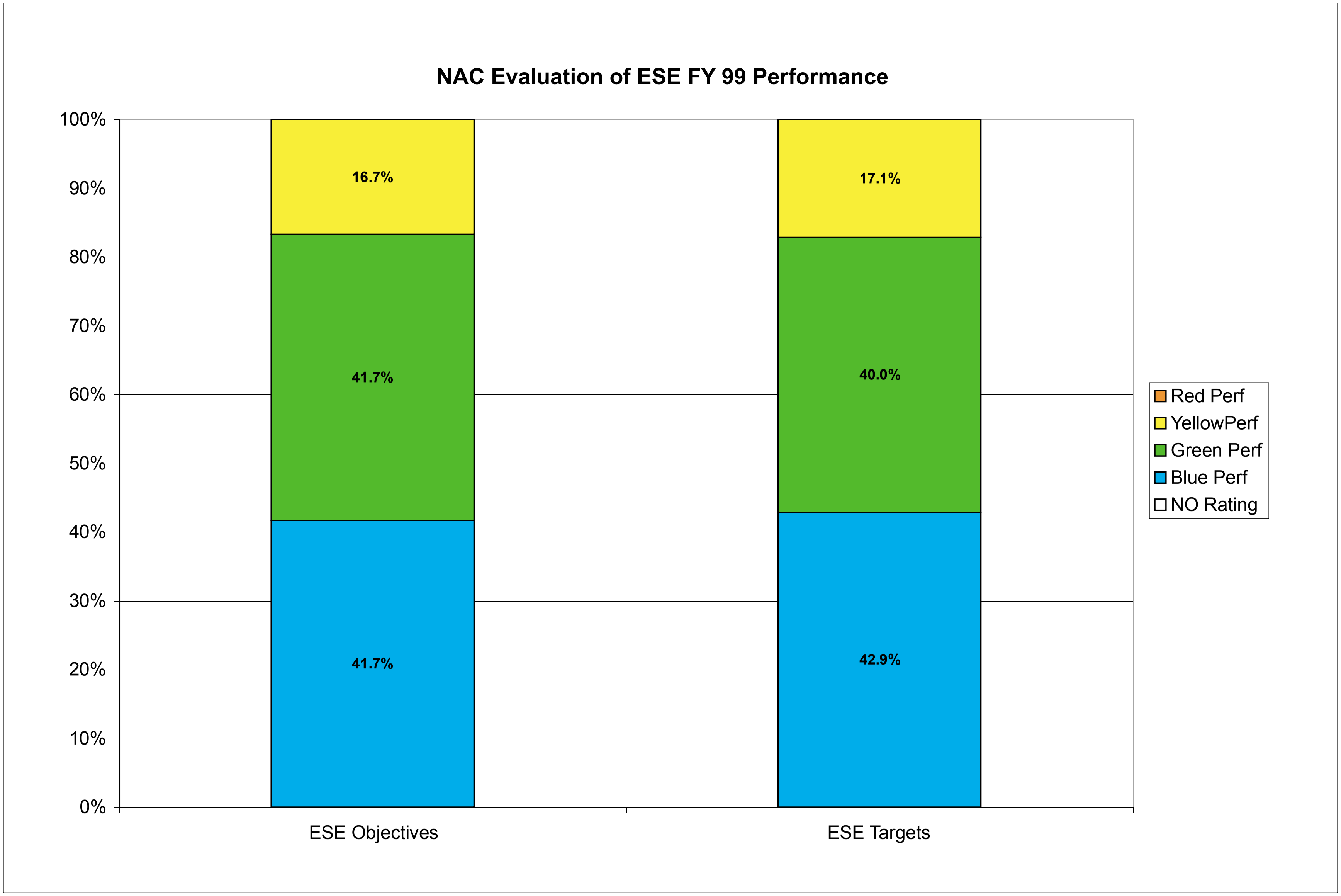
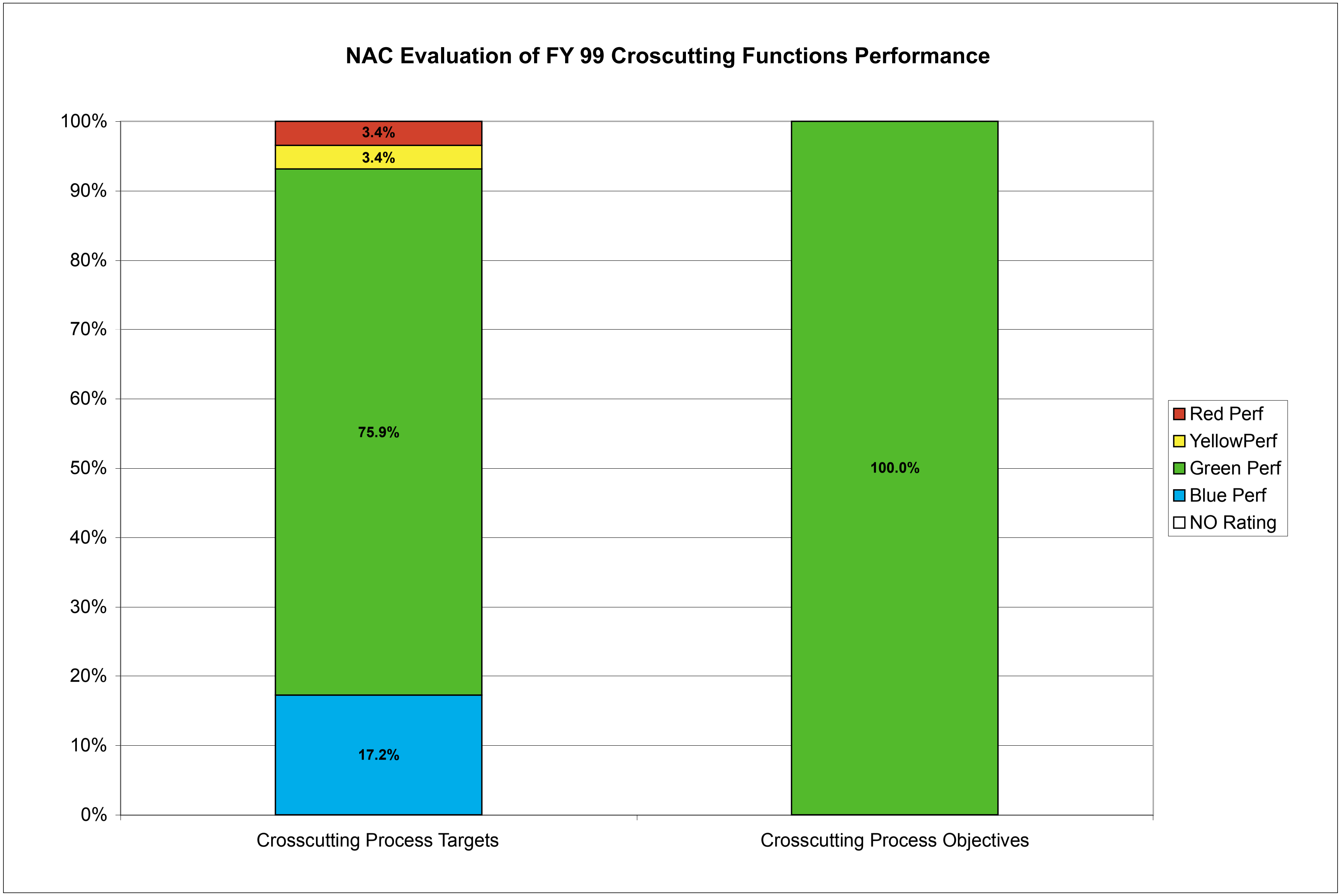
YellowPerf
Green Perf
Blue Perf
NO Rating


NAC Evaluation of SSE FY99 Performance
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
14.8%
70.4%
14.8%
87.5%
12.5%
21.1%
73.7%
5.3%
SSE Targets
SSE Objectives
SSAC Evaluation of Near term science objectives
Red Perf
Yellow Perf
Green Perf
Blue Perf
NO Rating


NAC Evaluation of ESE FY 99 Performance
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
16.7%
41.7%
41.7%
17.1%
40.0%
42.9%
ESE Objectives
ESE Targets
Red Perf
YellowPerf
Green Perf
Blue Perf
NO Rating


NAC Evaluation of FY 99 Croscutting Functions Performance
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
3.4%
3.4%
75.9%
17.2%
100.0%
Crosscutting Process Targets
Crosscutting Process Objectives
Red Perf
YellowPerf
Green Perf
Blue Perf
NO Rating

List of Acronyms

A

ACE	Advanced Composition Explorer
ADP	automated data processing
AES	Atmospheric Environmental Services (of Canada)
AIAA	American Institute of Aeronautics and Astronautics
AVHRR	Advanced Very High Resolution Radiometer

B

BR&C	Biomedical Research and Countermeasures (HEDS program)

C

CASI	Center for Aerospace Information
CDR	Critical Design Review
CERES	Clouds and the Earth's Radiant Energy System
CFIT	controlled flight into terrain
CSOC	Consolidated Space Operations Contract

D

DA	Data Analysis
DAAC	Distributed Active Archive Center
DRM	Design Reference Mission
DSN	Deep Space Network

E

EOCAP	Earth Observations Commercial Applications Program
EOS	Earth Observing System
EOSDIS	EOS Data and Information System
ERBE	Earth Radiation Budget Experiment
ERBS	Earth Radiation Budget Satellite
EROS	Earth Resources Observation System
ERS	ESA Remote Sensing Satellite
ESA	European Space Agency
EVA	extravehicular activity
EXPRESS	Expedite the Processing of Experiments to Space Station

F

FAA	Federal Aviation Administration
FACS	Financial and Contractual Status
fcc	face centered cubic

FGB	Functional Cargo Block (Russian acronym)
FIRE	First ISCCP Regional Experiment
FTE	Full-Time Equivalent
FY	fiscal year

G

GACP	Global Aerosol Climatology Project
GIS	Geographic Information System
GISS	Goddard Institute for Space Studies
GLOBE	Global Learning and Observations to Benefit the Environment
GOES	Geostationary Operational Environmental Satellite
GPRA	Government Performance and Results Act
GPS	Global Positioning System
GRACE	Gravity Recovery and Climate Experiment

H

HACA	hydrogen-abstraction/carbon-addition
HEDS	Human Exploration and Development of Space (Enterprise)
HPFTP	High-pressure Fuel Turbopump
HPOTP	High-pressure Oxidizer Turbopump
HRF	Human Research Facility

I

ICAO	International Civil Aviation Organization
ICESat	Ice, Cloud, and Land Elevation Satellite
IMP	Interplanetary Monitoring Platform
IPCC	International Panel on Climate Change
ISCCP	International Satellite Cloud Climatology Project
ISE	Intelligent Synthesis Environment
ISO	International Organization for Standardization
ISS	International Space Station
ITEA	International Technology Education Association

J

JPL	Jet Propulsion Laboratory

M

MEIT	Multi-Element Integrated Test
MGS	Mars Global Surveyor
MIP	Mars In-Situ Propellant

MODIS	Moderate Resolution Imaging Spectrometer
MOLA	Mars Orbiter Laser Altimeter
MPLM	Multi-Purpose Logistics Model
MSL	Microgravity Science Laboratory

N

NAC	NASA Advisory Council
NACA	National Advisory Committee for Aeronautics
NACC	NASA ADP Consolidation Center
NASA	National Aeronautics and Space Administration
NEAR	Near Earth Asteroid Rendezvous
NEW	NASA's Education Workshops
NISN	NASA Integrated Service Network
NIST	National Institute of Standards and Technology
NMP	New Millennium program
NOA	New Obligations Authority
NO_3	nitrogen trioxide
NOx	oxides of nitrogen
NRA	NASA Research Announcement
NSCAT	NASA Scatterometer
NSTA	National Science Teachers Association

O

OClO	chlorine dioxide
OLMSA	Office of Life and Microgravity Sciences and Applications
OV	Orbiter Vehicle

P

PBC	Performance Based Contract
PEM	Pacific Exploratory Mission
PICASSO-CENA	Pathfinder Instruments for Cloud and Aerosol Spacebourne Observations/ Climatologie Etendue des Nuages et des Aerosols
POAM	Polar Ozone and Aerosol Measurement

Q

QRAS	Quantitative Risk Assessment System
QuikSCAT	Quick Scatterometer

R

R&A	Research and Analysis
RESAC	Regional Earth Science Applications Center

rhcp	random hexagonal closed packed
RPA	Remotely Piloted Aircraft
RXTE	Rossi X-ray Timing Explorer

S

SAGE	Stratospheric Aerosol and Gas Experiment
SAR	Synthetic Aperture Radar
SAREX	Shuttle Amateur Radio Experiment
SBUV	Solar Backscatter Ultraviolet
SCIGN	Southern California Integrated GPS Network
SeaWiFS	Sea-viewing Wide Field-of-view Sensor
SF	Standard Form
SLD	Super-cooled Large Droplets
SMEX	Small Explorer
SOHO	Solar and Heliospheric Observatory
SOLSTICE	Solar/Stellar Irradiance Comparison Experiment
SP	Special Publication
SPARTAN	Shuttle Pointed Autonomous Research Tool for Astronomy
SRTM	Shuttle Radar Topography Mission
SSAC	Space Science Advisory Committee
SSME	Space Shuttle Main Engine
SSRMS	Space Station Remote Manipulator System
STI	Scientific and Technical Information (program)
STS	Space Transportation System

T

TEPC	tissue equivalent proportional counter
TIP	Telemedicine Instrumentation Pack
TOMS	Total Ozone Mapping Spectrometer
TOPEX	Ocean Topography Experiment
TRACE	Transition Region and Coronal Explorer
TRL	Technology Readiness Level
TRMM	Tropical Rainfall Measuring Mission
TSDIS	TRMM Data and Information System

U

UARS	Upper Atmospheric Research Satellite
UF	Utilization Flight
UNEP	United Nations Environment Programme
USDA	U.S. Department of Agriculture
USGCRP	U.S. Global Climate Research Program

V

VCL	Vegetation Canopy Lidar

W

WIRE	Wide-field Infrared Explorer
WMO	World Meteorological Organization
WORF	Window Observation Research Facility

Y

Y2K	Year 2000

National Aeronautics
and Space Administration

100

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